Prepared for:
AK Steel Corporation
West Chester, Ohio

Baseline Human Health Risk Assessment for the Former Armco Hamilton Plant Site, 401 Augspurger Road, New Miami, Ohio
Revised

Volume I of III
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List of Acronyms

ACS	American Cancer Society
AF	Absorption Fraction
AOC	Administrative Order on Consent
AOC	Area of Concern
AHP	Armco Hamilton Plant
ALM	Adult Lead Model
Armco	American Rolling Mill Company
ATSDR	Agency for Toxic Substances and Disease Registry
BCF	Bioconcentration Factor
BEHP	Bis(2-ethylhexyl)phthalate
bgs	below ground surface
BKSF	Biokinetic Slope Factor
BSAF	Biota-Sediment Accumulation Factor
CADD	Chronic Average Daily Dose
CAS	Chemical Abstracts Service
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CG&E	Cincinnati Gas and Electric Company
COC	Constituent (or Chemical) of Concern
COG	Coke Oven Gas
COPC	Constituent (or Chemical) of Potential Concern
CSF	Cancer Slope Factor
CSM	Conceptual Site Model
CTE	Central Tendency Exposure
DAD	Dermally Absorbed Dose
DA_{Event}	Calculation of the dose absorbed per unit area per event
DAF	Dermal Absorption Fraction
DERR	Division of Emergency and Remedial Response
DL	Detection Limit
EFH	Exposure Factors Handbook
ELCR	Excess Lifetime Cancer Risk
EPC	Exposure Point Concentration
FDA	Food and Drug Administration
GSD_i	Individual blood lead concentration geometric standard deviation
HCP	Hamilton Coke Plant
HEAST	Health Effects Assessment Summary Tables
HHAWQC	Human Health Ambient Water Quality Criteria
HHRA	Human Health Risk Assessment
HI	Hazard Index
HQ	Hazard Quotient
IEUBK	Integrated Exposure Uptake Biokinetic Model
IRIS	Integrated Risk Information System
JEM	Johnson and Ettinger Model
LADD	Lifetime Average Daily Dose

LMS	Linearized Multi-Stage
LOAEL	Lowest Observed Adverse Effect Level
MADEP	Massachusetts Department of Environmental Protection
MCL	Maximum Contaminant Level
MRL	Minimal Risk Level
NCDC	National Climatic Data Center
NCEA	National Center for Environmental Assessment
NOAEL	No Observed Adverse Effect Level
OEHHA	Office of Environmental Health and Hazard Assessment
OHM	OH Materials Corporation
OSWER	Office of Solid Waste and Emergency Response
PAH	Polynuclear Aromatic Hydrocarbon
PC	Permeability Constant
PCB	Polychlorinated Biphenyls
PEF	Particulate Emission Factor
PM_{10}	Particulate Matter of 10 Microns or Less in Aerodynamic Diameter
PPRTV	Provisional Peer-Reviewed Toxicity Value
PRG	Preliminary Remediation Goal
QAPP	Quality Assurance Project Plan
R	Fetal/Maternal blood lead concentration ratio
RAGS	Risk Assessment Guidance for Superfund
RDA	Recommended Daily Allowance
RfC	Reference Concentration
RfD	Reference Dose
RGO	Remedial Goal Option
RI/FS	Remedial Investigation/Feasibility Study
RL	Reporting Limit
RME	Reasonable Maximum Exposure
SLERA	Screening Level Ecological Risk Assessment
SOW	Scope of Work
SQL	Sample Quantitation Limit
SVOC	Semi-Volatile Organic Compound
TAL	Target Analyte List
TCDD	Tetrachloro-dibenzo-p-dioxin
TCDD-TEQ	TCDD Toxic Equivalence Concentration
TCE	Trichloroethene
TCL	Target Compound List
TEF	Toxicity Equivalency Factor
TRW	Technical Review Workgroup
UCL	Upper Confidence Limit
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WHO	World Health Organization
VF	Volatilization Factor
VOC	Volatile Organic Compound

Executive Summary

This executive summary summarizes the baseline human health risk assessment (HHRA) for the AK Steel Corporation former Armco Hamilton Plant (AHP) (the "Site") in New Miami, Ohio. The HHRA was conducted in accordance with the RI/FS Work Plan, the Administrative Order on Consent (AOC), applicable agency guidance, and in accordance with responses to USEPA comments on the draft HHRA submitted in September 2006. It follows the four-step paradigm for human health risk assessments developed by USEPA (USEPA, 1989).

Based on an analysis of Site data and consistent with USEPA guidance for risk assessment (USEPA, 1989), 54 constituents of potential concern (COPCs) were identified and carried through quantitative risk calculations in ten identified Areas of Concern. The latest available toxicity values were identified for each COPC considering both potential carcinogenic and noncarcinogenic effects. The HHRA addressed potential exposures to a wide variety of environmental media including surface and subsurface soil, groundwater, hydric soil, sediment, surface water, outdoor air, indoor air, shower air, and fish that may accumulate COPCs. While the Site is not currently in use, six potential human receptors were evaluated: 1) Future on-site worker, 2) Future construction worker, 3) Current and future trespasser 4) Current and future recreational angler, 5) Current and future off-site resident, and 6) Hypothetical future on-site resident.

At the request of USEPA, it was assumed that the Site could be developed for residential purposes in the future. This is unlikely to occur, and it is anticipated that a deed restriction will be obtained to prohibit future residential development of the Site. Risk estimates in excess of 10^{-4} and/or a hazard index of 1 were identified under the hypothetical future on-site residential scenario for all exposure areas for a number of COPCs. *Based on these results, no further evaluation of the future on-site residential scenario* is recommended, and institutional controls should be placed on the property such that residential development and use of groundwater are prohibited.

Throughout the HHRA, conservative (i.e., health-protective) assumptions were used to quantify factors associated with human exposure, such as soil ingestion rate, inhalation rate, body surface area exposed, exposure frequency, and exposure duration (number of years that someone is assumed to be exposed). The concentrations of COPCs at potential points of exposure were also conservatively estimated, and consisted of upper-bound and/or maximum detected concentrations. If measurement data from the Site CERCLA Remedial Investigation were not available for a particular medium, such as indoor air or fish tissue, concentrations were estimated using conservative modeling approaches. Each potential exposure pathway for each receptor was evaluated for both potential carcinogenic and noncarcinogenic effects. Potential risks were calculated and summed for each receptor and compared to the USEPA's target risk levels, which are:

- the target risk range of 10^{-6} to 10^{-4} for COPCs with potential carcinogenic effects, and
- a hazard index of 1 (summed on a toxic endpoint basis) for COPCs with potential noncarcinogenic effects.

As requested by USEPA, any COPC that caused an exceedance of 10^{-6} risk level or a hazard index of 1 (per toxic endpoint) for a particular receptor was designated a COC. However, this is a conservative approach and not all of these COCs or areas are anticipated to warrant remedial action. It should be noted that USEPA provides the following guidance (USEPA, 1991a):

> "Where the cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4}, and the non-carcinogenic hazard quotient is less than 1, action generally is not warranted unless there are adverse environmental impacts." and,

"The upper boundary of the risk range is not a discrete line at 1 x 10^{-4}, although EPA generally uses 1 x 10^{-4} in making risk management decisions. A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions."

The assumptions regarding exposure frequency and duration in the Reasonable Maximum Exposure (RME) risk estimates are very conservative. As a result, a second scenario was considered in this risk assessment to evaluate the potential risks under a more average scenario, the Central Tendency Exposure (CTE). As requested by USEPA, the same EPCs used under the RME scenario were used under the CTE scenario. The only difference in the CTE risk estimate is that which results from reductions in exposure assumptions selected. This is a very conservative approach, considering there was no allowance for potentially more representative and less conservative EPCs in the calculations of CTE risk.

Site Soil

Based on the results of the baseline HHRA, the following compounds with a cumulative RME cancer risk above 10^{-6} and/or a cumulative noncancer HI of 1 (per toxic endpoint) were identified as potential COCs in soil:

- arsenic, benzene, lead, manganese, potentially carcinogenic PAH, PCBs, and naphthalene in soil,
- potentially carcinogenic PAH in Riparian Area (AOC 22) hydric soil,

It is important to note that arsenic and potentially carcinogenic PAHs were consistent with site-specific background in surface soils of every AOC at the Site. Arsenic and lead were also consistent with background in subsurface soils across the Site.

Site risks were evaluated within the full USEPA target risk range of 10^{-6} to 10^{-4} to provide a more comprehensive and transparent interpretation of the potential risk. At a 10^{-4} cumulative Site risk level and an HI of 1, potential RME soil COCs and areas consist of the following:

- One or more potentially carcinogenic PAH in soil at AOC 1, Southern Parcel and AOC 13,
- Manganese in Block A soil,
- Naphthalene in AOC 1 and AOC 13 soil,
- PCBs in AOC 1 soil,
- When the results of the CTE analysis are considered, and assuming a cumulative Site risk of 10^{-4}, the vast majority of the Site is within the USEPA target risk range under CERCLA. Only naphthalene in AOC 1 and AOC 13 soil exceeds the USEPA target noncarcinogenic hazard index of 1, due to volatilization into ambient air and subsequent inhalation exposure by future workers.

The naphthalene hazard index in AOC 1 (hazard index of approximately 2 for a future construction worker and on-site worker) is driven by one subsurface soil sample (AOC1CA12 with 1100 mg/kg naphthalene). Naphthalene concentrations in the remaining 33 surface and subsurface soil samples from AOC 1 are less than 2.2 mg/kg, with the exception of one sample containing 10 mg/kg naphthalene.

The naphthalene hazard index in AOC 13 is driven by multiple subsurface soil samples with elevated concentrations, including the sample with the highest naphthalene concentration detected in AOC 13 soil. The EPC for naphthalene in AOC 13 combined soil is 2,860 mg/kg which exceeds the soil saturation limit for naphthalene of 375 mg/kg. USEPA guidance (2002b) states that the soil saturation limit represents an upper bound on the applicability of the volatilization factor model used to derive the soil to outdoor air concentrations. The guidance also states that for compounds that are solid at room temperature (i.e., naphthalene), concentrations above the soil saturation limit do not pose a significant inhalation risk. Therefore, the potential hazard for naphthalene is overstated (by a factor of 7.6) through the use of the statistically derived EPC rather than the soil saturation limit as the EPC. If the soil saturation limit is used in lieu of the statistically derived EPC (as allowed by the volatilization model), the resulting inhalation HI for naphthalene in AOC 13 soil would be approximately eight-fold lower (hazard index of approximately 2). Further, the models used by USEPA to estimate volatilization from soil to ambient air are known to be conservative (e.g., assume infinite source), as discussed in USEPA guidance (2002b). It is very likely that use of more refined volatilization modeling methods, such as EMSOFT, would result in acceptable ambient air concentrations of naphthalene and the resulting hazard index for naphthalene in AOC 1 and AOC 13 would drop to below 1.

Site Groundwater

The identification of groundwater COCs was based on the presumption of future use of on-site groundwater as drinking water and is overly conservative, given that groundwater is not currently used as an on-site drinking water source and it is anticipated that institutional controls will be proposed to prohibit use of groundwater at the Site as a drinking water source. Thus, the drinking water pathway evaluated in this risk assessment is completely hypothetical. The HHRA also assumes that Site groundwater migrates off-site and reaches the Hamilton North Wellfield without any dilution or attenuation. This is clearly an overly conservative assumption. Available hydrogeologic data suggest that intermediate groundwater discharges to the river and does not migrate beneath the river off-site. This is significant because concentrations of COCs are essentially limited to the shallow and intermediate groundwater, while deep groundwater shows no or very limited impacts from Site activities.

Based on the results of the baseline HHRA, the following compounds with a cumulative RME cancer risk above 10^{-6} and/or a cumulative noncancer HI of 1 (per toxic endpoint) were identified as potential COCs in groundwater:

Arsenic	Cyanide
Benzene	Other inorganics and organics in AOC13
Potentially carcinogenic PAH	

Arsenic was detected in soils across the Site and was consistent with background in every AOC. It is unlikely that there is a source to Site groundwater (above background) that would not also be found in Site soils. It is likely that the source of arsenic in Site groundwater is background levels of arsenic in soil.

Site risks were evaluated within the full USEPA target risk range of 10^{-6} to 10^{-4} to provide a more comprehensive and transparent interpretation of the potential risk. At a 10^{-4} cumulative Site risk level and an HI of 1, potential RME groundwater COCs and areas are reduced to arsenic, cyanide, and multiple organics in groundwater in AOC 13 wells (for both on-site and off-site hypothetical future drinking water scenarios). As noted above, a restriction against groundwater use on-site is anticipated. Although potential COCs were identified for completeness, remedial actions may not be warranted because an institutional control is expected to prevent the exposure that could result in potentially unacceptable risks.

Great Miami River

The Great Miami River is an industrialized River that has historically received and continues to receive point source discharges of industrial and municipal wastewater as well as non-point sources such as stormwater runoff. The accumulation of chemical pollutants such as PAHs, metals and PCBs in the sediments of rivers flowing through populated and industrialized areas is well documented and the Great Miami is an example of such a river. Select metals, PAHs, and PCBs are present throughout the river (including Upstream of the Site) at concentrations above human health soil screening benchmarks typically used for sediment exposure. PAHs, PCBs (modeled in fish tissue from sediment) and mercury (modeled in fish tissue from surface water) were identified as COCs in the Great Miami River.

Mercury in the Great Miami River surface water and PAHs and PCBs in Great Miami River sediment were identified in upstream samples as well as those adjacent to the Site. The levels of mercury measured in the Great Miami River adjacent to and upstream of the Site represent total mercury, and only the dissolved fraction is expected to bioaccumulate into fish. USGS fish tissue measurements of methyl mercury from the Great Miami River (0.113 mg/kg wet weight) were below the predicted fish tissue concentrations (0.34 and 1.54 mg/kg). These data suggest that the use of total mercury surface water concentrations results in an overestimate of the fish tissue burden. Mercury was identified as a COPC in Site soil, however is consistent with background levels, and is not a COC in Site groundwater or river sediment. Mercury in surface water of the Great Miami River is, therefore, considered to be related to background conditions in the Great Miami River and not the Site.

A default biota-sediment accumulation factor (BSAF) was used to estimate the concentration of PCBs in fish tissue based on sediment and total organic carbon concentrations in the Great Miami River. The highest predicted fish tissue concentration was in the upstream reach of the river and was approximately 4 times higher than that derived for the portion of the river adjacent to the Site. The overconservatism in the BSAF model is further supported by actual measured PCB concentrations in fish samples collected from the Great Miami River in the vicinity of the Site. Based on Ohio EPA fish monitoring data from 1993, 1998, and 2002 for carp, smallmouth bass, catfish and redhorse, total PCBs in fish tissue range from non-detect to approximately 1 mg/kg, well below modeled concentrations using USEPA's default BSAF. When upgradient and regional concentrations of PCBs in sediment and mercury in surface water are considered, potential fish consumption risks for a recreational angler drop below the CERCLA threshold and are within target risk benchmarks. Therefore, PCB concentrations in sediment, mercury in surface water and both estimated in fish tissue are considered to be related to background conditions in the Great Miami River and not the Site.

The evaluation of potentially carcinogenic PAHs in Great Miami River sediment adjacent to the Site resulted in potential direct contact risks in excess of 1 x 10^{-6}, and for two PAH, in excess of 1 x 10^{-5}. This risk is driven largely by one sediment sample (SD-6), and to a lesser extent nearby sample SD-31. Potentially carcinogenic PAH concentrations in other sediment samples along the reach of the Great Miami River adjacent to the Site are 10 to 100-fold lower than concentrations in these two samples. It is not known if the compounds are a result of historical release, background conditions, or disturbance and deposition during a high water event. The presence of low levels of COCs along the river may represent background conditions of the river system and be the result of sediment redistribution in the river during storm events. PAHs are present in upstream sediments at concentrations comparable to levels in the reach adjacent to the Site, and indicative of the historically industrial nature of the river. Therefore, PAH concentrations in sediment are considered to be related to upstream conditions in the Great Miami River and not solely attributable to the Site.

Based on the body of data presented in this risk assessment, including, but not limited to, the documented upstream sediment concentrations of several COCs; the ubiquitous nature of key Site COCs such as PAHs in industrialized river systems, the absence of greater detections of potentially bioaccumulative compounds in the reach of the river adjacent to the Site versus upstream, no human health risk above background (or upstream conditions) is present to warrant additional evaluation or action in the Great Miami River. Therefore, it is concluded that no further investigation of or response action for the Great Miami River is warranted for this Site under CERCLA and the NCP.

Remedial Goal Options and Background

All of the potential COCs identified based on the results of the RME risk characterization were carried forward into the development of remedial goal options (RGOs). RGOs for potentially carcinogenic COCs were derived for three risk levels within the USEPA's target risk range (10^{-6}, 10^{-5}, and 10^{-4}) to provide a range of RGOs.

USEPA guidance does not require remediation to levels below background (USEPA, 2002f). Further, USEPA confirmed the approach of taking background issues into consideration in the Uncertainty Analysis, and addressing site-specific background issues at the end of the risk characterization (USEPA, 2008b). When site-specific background is considered, a number of the COCs are eliminated including arsenic and lead in soil in all areas, and potentially carcinogenic PAH in the soil of most areas. When site-specific background is factored into the RME risk results, Site risks are below 10^{-6} in several exposure areas including AOC 2, AOC 18 & 21, AOC 19, and the Riparian Area (AOC 22). When upgradient and regional concentrations of PCBs in Great Miami River sediment and mercury in Great Miami River surface water are considered, potential fish consumption risks for a recreational angler also drop below the CERCLA threshold and are noted to be within target risk benchmarks. The impact of the background evaluation on the risk results for this Site should not be underestimated, as it is a critical factor in interpreting the significance of the HHRA findings and the RGOs.

By their nature, regulatory risk assessments under CERCLA are intentionally health-protective. Upper-bound assumptions are used throughout the process, and potential human exposures are evaluated using RME assumptions. When estimated RME risks are within or below the USEPA target levels, confidence is high that there are no unacceptable risks due to the conservative nature of the scenario. As part of the risk assessment process, an uncertainty analysis was performed to evaluate assumptions that introduce the greatest uncertainty, to estimate risks using more "average" exposures, and to consider whether the constituents at the Site may be attributable to natural or anthropogenic background, and not past Site practices.

A number of COCs, media, and areas of concern were identified when the lower end of the USEPA's target risk range (10^{-6} to 10^{-4}) was used as a trigger for further evaluation. However, the majority of the potential carcinogenic risks estimated in this baseline HHRA do not exceed the upper end of the USEPA's target risk range of 10^{-6} to 10^{-4} for RME scenarios. Since remedial actions are typically not warranted where the cumulative carcinogenic Site risk to an individual based on RME for both current and future land use is less than 10^{-4}, and the non-carcinogenic hazard quotient is less than 1, remedial action is not expected to be necessary for much of this Site. Information resulting from the evaluation of the full risk range under CERCLA is provided in this baseline risk assessment, including the results of background, CTE, and RGO evaluations, such that informed risk management decisions can be made for Site soils and groundwater.

1.0 Introduction

On April 29, 2002, the United States Environmental Protection Agency (USEPA) and AK Steel Corporation (AK Steel) entered into an Administrative Order on Consent (AOC; EPA Docket No. V-W-'02-C-692) pursuant to the Comprehensive, Environmental Response, Compensation and Liability Act of 1980 (CERCLA) for a Remedial Investigation/Feasibility Study (RI/FS) at the former Armco Hamilton Plant (AHP) facility (the Site) in New Miami, Ohio. Figure 1-1 presents the Site Location.

As stated in the AOC and the Statement of Work (SOW) incorporated in the Order, the objectives of the RI/FS are as follows:

- To determine the nature and extent of contamination and any threat to the public health, welfare, or the environment, if any, caused by the release or threatened release of hazardous substances, pollutants, or contaminants at or from the Site, by conducting a remedial investigation, including a human health and ecological risk assessment;

- To evaluate the nature and extent of hazardous substances, if any, at and from the AHP property and off-property areas where hazardous substances, if any, from the property have or may have come to be located, and also assess the risk from these hazardous substances (if any) on human health and the environment;

- To determine and evaluate alternatives for remedial action (if any) to prevent, mitigate, or otherwise respond to or remedy any release or threatened release of hazardous substances, pollutants, or contaminants at or from the Site or facility, by conducting a feasibility study; and

- To evaluate alternatives for addressing the impact (if any) to human health and the environment from hazardous substances at the Site.

The purpose of the baseline human health risk assessment (HHRA) is to characterize potential risks to human receptors who may come into contact with site-related hazardous substances as well as risks to nearby populations.

The HHRA was conducted to be consistent with USEPA guidance for conducting a risk assessment including, but not limited to, the following:

- Risk Assessment Guidance for Superfund (RAGS): Volume 1 - Human Health Evaluation Manual (Parts A and E) (USEPA, 1989 and 2004a).

- Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions (USEPA, 1991a).

- USEPA Soil Screening Guidance: User's Guidance Manual, and Technical Background Document (USEPA, 1996a,b).

- Human Health Evaluation Manual Supplemental Guidance; Standard Default Exposure Factors. OSWER Directive 9285.6-03 (USEPA, 1991b).

- Exposure Factors Handbook (EFH) (USEPA, 1997a).

- Land Use in CERCLA Remedy Selection Process. OSWER Directive No. 9355.7-04 (USEPA, 1995a).

This revised HHRA has also been performed to address USEPA's comments on the draft HHRA report, as specified in AK Steel's September 21, 2007 Responses to U.S. EPA Comment Letter dated August 3, 2007 and USEPA's additional comments dated May 15, 2008. USEPA comments on the draft HHRA and AK Steel responses are provided in Appendix K. The HHRA also has been revised to incorporate the laboratory analytical results of additional environmental data collected at the site in May through July 2008.

The baseline HHRA has been conducted in accordance with the four-step paradigm for human health risk assessments developed by USEPA (USEPA, 1989); these steps are:

- Data Evaluation and Hazard Identification
- Toxicity Assessment
- Exposure Assessment
- Risk Characterization

Report Organization

A description of the Site is presented in Section 2.0. The four steps of the baseline HHRA are presented in Sections 3.0 through 6.0 of this report. Section 7.0 presents the summary and conclusions and Section 8.0 provides the references. A summary of the information presented in each section of the report follows.

- Section 2.0 – Site Characterization. This section discusses the Site and its environs, describes source areas, potential migration pathways, and potentially impacted media.
- Section 3.0 – Data Evaluation and Hazard Identification. This section presents a summary of the Site data for use in the HHRA, and the results of the process used for the selection of constituents of potential concern (COPCs) to be quantitatively evaluated in the baseline HHRA.
- Section 4.0 – Dose-Response Assessment. The dose-response assessment evaluates the relationship between the magnitude of exposure (dose) and the potential for occurrence of specific health effects (response) for each COPC. Both potential carcinogenic and noncarcinogenic effects are considered. This section presents the quantitative dose-response values used in the baseline HHRA. The most current USEPA verified dose-response values are used when available.
- Section 5.0 – Exposure Assessment. The purpose of the exposure assessment is to provide a quantitative estimate of the magnitude and frequency of potential exposure to COPCs by a receptor. This section presents a conceptual site model (CSM) for human health. Potentially exposed individuals, and the pathways through which those individuals may be exposed to COPCs are identified based on the physical characteristics of the Site, as well as the current and reasonably foreseeable future uses of the Site and surrounding area. The extent of a receptor's exposure is estimated by constructing exposure scenarios that describe the potential pathways of exposure to COPCs and the activities and behaviors of individuals that might lead to contact with COPCs in the environment.
- Section 6.0 – Risk Characterization. Risk characterization combines the results of the exposure assessment and the toxicity assessment to derive site-specific estimates of potentially carcinogenic and noncarcinogenic risks resulting from both current and reasonably foreseeable potential human exposures to COPCs. The results of the risk characterization are used to identify constituents of concern (COCs), which are a subset of those COPCs whose risks result in an exceedance of the target risk range of 1×10^{-6} to 1×10^{-4} for potential carcinogens and a target Hazard Index of one for noncarcinogens (that act on the same target organ) per USEPA guidance (USEPA, 1991a). While remedial action may not be warranted where potential risks exceed 10^{-6}

but are below 10^{-4}, as requested by USEPA for this HHRA, any COPC that causes an exceedance of 10^{-6} risk level for a particular receptor is designated a COC. The target risk levels used for the identification of COCs are based on USEPA direction for the Site. It should be noted that, USEPA provides the following guidance (USEPA, 1991a):

> "Where the cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4}, and the non-carcinogenic hazard quotient is less than 1, action generally is not warranted unless there are adverse environmental impacts." and,
>
> "The upper boundary of the risk range is not a discrete line at 1×10^{-4}, although EPA generally uses 1×10^{-4} in making risk management decisions. A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions."

Therefore, while COCs have been identified using a 10^{-6} risk level, further risk management determinations will be made and remedial action may not be warranted for all COCs.

- Section 7.0 – Uncertainty Analysis. Within any of the steps of the risk assessment process described above, assumptions must be made due to a lack of absolute scientific knowledge. Some of the assumptions are supported by considerable scientific evidence, while others have less support. The assumptions that introduce the greatest amount of uncertainty in this risk evaluation are discussed in Section 7.0. The Uncertainty Analysis includes a Central Tendency Evaluation (CTE) for specific RME receptor/pathway combinations that exceed target risk levels. The Uncertainty Analysis also includes a background evaluation for key COCs.

- Section 8.0 – Remedial Goal Options. This section discusses the derivation of Remedial Goal Options (RGOs) for constituents identified as COCs for the Site.

- Section 9.0 – Summary and Conclusions. This section presents summarizes the results and conclusions of the baseline HHRA.

- Section 10.0 – This section presents the references cited in the text.

Tables and figures are provided after Section 10.

2.0 Site Characterization

The Site is defined in the AOC and SOW and includes the property located at 401 Augspurger Road, Butler County, Ohio, which is approximately 252 acres divided between two parcels of land immediately adjacent and to the south of Augspurger Road (southern parcel) and immediately adjacent and north of Augspurger Road (northern parcel). *Figure 1-1 presented the Site location. Figure 2-1 presents the Site plan.*

The southern parcel is bordered to the east and south by the Great Miami River, to the west by a rail yard operated by CSX Transportation and to the north by Augspurger Road. The southern parcel is located in Sections 21 and 22 in St. Clair Township, Butler County, Ohio, and is within the city limits of New Miami, Ohio. The southern parcel, now vacant, formerly contained the Hamilton Coke Plant (HCP), two blast furnaces for ore making, a sinter plant, and associated coal handling facilities. Very little evidence remains of the HCP and the blast furnace area, which were decommissioned/ demolished in 1988-89 and 1993-95, respectively. The roadway through the property remains and a large hilly area exists on the western side of the property where the blast furnaces were located. Some concrete slabs remain, indicating where buildings and a large gas collector were located. The majority of the Site is covered with tall grass and occasional trees. This parcel is surrounded by a chain-link fence and remains locked.

The northern parcel is located north of Augspurger Road and is bounded to the west-northwest by a rail yard operated by CSX Transportation, to the northeast by Jackson Road, to the east-southeast by residential property, and to the south by Augspurger Road. This north parcel lies within Section 15 in St. Clair Township, Butler County, Ohio. A CSX rail line bisects this parcel, east to west, parallel to Augspurger Road. The portion of the parcel between Augspurger Road and the CSX rail line was used to store coal for the HCP and later for storing air scrubber sludge and dust from the blast furnaces. A former slag processing plant was located on the northwestern portion of the north parcel. No buildings are present at the location of the former slag plant; however, concrete block walls remain in one area and a large demolished concrete structure remains in another area.

A closed landfill is located on the east side of this northern parcel north of the east-west rail line. The closed landfill is bounded to the north and west by slag piles, abandoned rail lines and a partially wooded area; to the east by a wooded area containing a drainage ditch; and to the south by the east-west CSX rail line. The closed landfill is approximately 4-5 acres in size, has approximately 3-5 feet of topographic relief and is covered with tall grass (Figure 6 of the Draft Remedial Investigation Report (ENSR, 2006)). Closing of the landfill was completed in October 1980 in accordance with the necessary provisions of Ohio EPA's then-existing solid waste landfill closure rules, OAC Rule 3745-27-10 titled "Closure of Sanitary Landfill." At closure, the material in the landfill was stabilized with slag, graded to slopes greater than 1% and less than 25% to facilitate surface water runoff and drainage, covered with two feet of compacted low permeability clay, then with topsoil, and then seeded with grass to complete a dense cover. The landfill remains completely surrounded by a chain-link fence, has locked gates and "No Trespassing" signs posted to prevent unauthorized access.

Subgrade pipelines remaining on the Site include the following:

- a Cincinnati Gas and Electric Company (CG&E) pipeline on the east side of the southern parcel which was used to supply gas to the blast furnace area;
- a decommissioned predominately 16-inch diameter underground coke oven gas (COG) pipeline located on the eastern portion of the southern parcel and the western portion of the northern parcel, and located off-site between the Site and the AK Steel Middletown Works; and
- various decommissioned underground process lines and sewer lines on the southern parcel associated with past plant operations.

Site History and Past Operations

Prior to development of the Site, a coke plant (The Otto Coke Company) existed immediately west of (and adjacent to) the western property boundary of the southern parcel of the Site. The Otto coke plant operated until 1913.

The southern parcel of the Site was initially developed in July 1907 as the Hamilton Iron and Steel Company which built a blast furnace plant on the subject property. The plant operated periodically until closure in 1912. The Koppers Company of Pittsburgh, Pennsylvania, purchased the plant in 1927 and renamed the plant the Hamilton Coke & Iron Company. At that time, 45 Becker-type coke ovens were erected, along with ancillary coke by-product equipment to recover tar, light oil, naphthalene, phenol, and ammonia sulfate from cokemaking operations. A former COG gas holder (approximately five million cubic feet capacity) was also constructed and operated by CG&E. In 1932, a new boiler plant was built for the blast furnace area. The boilers used blast furnace gas as a primary fuel and No. 6 fuel oil and coal/coke as backup fuel. A second blast furnace was constructed on the southern parcel by Koppers in 1937.

Three water wells (installed in the sand and gravel unit at approximately 200 ft bgs) were drilled and installed in 1927 for blast furnace cooling purposes, each having a capacity of 2,400 gallons per minute. These wells were abandoned by 1948. Five additional wells were drilled and installed (between 1927 and 1956) having a total source capacity of 8,000 gallons per minute. The American Rolling Mill Company (Armco) purchased the plant from Koppers in 1937. Koppers maintained a leased portion of the plant area (adjacent to the benzol yard) for the manufacturing of road tar.

Two settling ponds were installed in the 1930s to handle scrubber wastewater from the blast furnace flue gas. Sludge was periodically dredged from the two settling ponds and stored in piles in the railyard area on the northern parcel (north of Augspurger Road). This "scrubber" sludge was reused in Armco's iron production due to its high iron content. Armco also sold some of the scrubber sludge to other steel companies. Armco estimated that as much as 180,000 cubic yards might have been stored at the Site. Between 1989 and 1990, the remaining approximate 18,000 cubic yards of scrubber sludge were transported to Armco's Sinter Plant in Middletown, Ohio. Use of the settling ponds was discontinued in 1990, upon shutdown of the last blast furnace. The ponds were cleaned out in 1993 and permanently closed in 1995 by filling in the drained ponds with on-site fill material.

A major plant upgrade program took place in 1977 and 1978, which included the installation of state-of-the-art water pollution control facilities to treat ammonia still waste, benzol plant waste, quench tower waste, and non-contact cooling water at the coke plant. In addition, the phenol recovery process was removed and replaced with a biological wastewater treatment plant.

Coke plant operations ceased in 1982. At the time when operations ceased, cokemaking occurred in four batteries with a total of 110 ovens. In 1982, coke production stood at approximately 1,600 tons per day. Coke operations covered the majority of the south parcel. Blast furnace activities ceased in 1990. The No. 2 blast furnace was shut down in 1986 and the No. 1 blast furnace in 1990. Prior to the time when operations ceased, each furnace was producing approximately 1,000 tons of iron per day.

In 1994, Armco Steel L.P. conveyed title to the Site to AK Steel Corporation.

At the time of total plant closure, 14 water wells existed on the property, which included one well used by the Miami Conservancy District for monitoring purposes. Wells were installed within the sand and gravel aquifer to approximately 200 ft bgs and properly abandoned upon plant closure. The approximate locations of former production wells on the Site are shown on Figures 7, 8 and 9 of the Draft Remedial Investigation Report (ENSR, 2006).

At the height of operation, the plant facility had four stormwater outfalls (i.e., 001, 002, 003, and 004).

- Outfall 001 drained stormwater from the southern end of the parcel. In addition, any overflow from the settling ponds drained though this outfall.
- Outfall 002 drained the southeast part of the southern parcel and also contained boiler blowdown and treated sanitary discharge.
- Outfall 003 was used primarily for non-contact cooling water from a cooling tower, as well as stormwater.
- Outfall 004 drained stormwater from the area around the by-products building.

OH Materials Corporation (OHM) was contracted in 1988-89 to perform insulation removal, decontamination, and demolition of the coke plant facility. Over the time frame from 1993-1995, the blast furnaces and other buildings and structures at the Site were decommissioned and demolished. No manufacturing has occurred on the Site since that time, and no aboveground structures remain on the Site.

The southern half of the northern parcel (i.e., south of the east-west rail line) was initially used to store raw material (coal) for the coking operations. As discussed above, air scrubber sludge was periodically dredged from the two settling ponds associated with the blast furnaces on the southern parcel.

The western portion of the northern parcel (an area covering approximately 38 acres) was leased to American Materials Corporation for operation of a slag plant – slag being a by-product material of the iron production operations on the southern parcel. The slag material was crushed, separated and the iron content within the slag was reused in the Hamilton plant's blast furnaces. The remaining slag material was sized and sold.

In addition, a landfill, approximately 4-5 acres in size, was active on the northern parcel during the early 1960s to 1980, primarily for the disposal of tar decanter sludge (a by-product of the coking operations). After closure of the landfill in 1980, tar decanter sludge was disposed of at the CECOS facility in Williamsburg, Ohio until the coke plant was shut down in 1982. Slag, rubble, and general trash were also disposed of in the landfill. Little information exists regarding the depth of burial and waste disposal practices.

Closing of the landfill was completed in October 1980. At closure, the material in the landfill was stabilized with slag, graded to slopes greater than 1% and less than 25% to facilitate surface water runoff and drainage, covered with two feet of compacted low permeability clay, then with topsoil, and then seeded with grass to complete a dense cover. The landfill remains completely surrounded by a chain-link fence, has locked gates and "No Trespassing" signs posted to prevent unauthorized access.

3.0 Data Evaluation and Hazard Identification

The purpose of the data evaluation and hazard identification process is two-fold: 1) to evaluate the nature and extent of release of site-related constituents present at the Site; and 2) to select a subset of constituents identified as constituents of potential concern (COPCs) for quantitative evaluation in the baseline human health risk assessment. This step of the risk assessment involved compiling and summarizing the RI/FS data relevant to the risk assessment, and selecting COPCs based on a series of screening steps.

3.1 Media Sampled in Support of RI/FS

Sampling conducted in support of the RI/FS for this Site includes the following media:

- On-site surface soil (0-2 ft bgs);
- On-site subsurface soil (greater than 2 ft bgs);
- Off-site surface soil (0-2 ft bgs) (AOC 19 and background);
- Off-site subsurface soil (greater than 2 ft bgs) (AOC 19 and background);
- Slag;
- On-site groundwater (shallow, intermediate, and deep);
- Intermittent stream sediment (AOC 7);
- Intermittent stream surface water (AOC 7);
- Riparian Area hydric soil (AOC 22);
- Great Miami River sediment; and
- Great Miami River surface water.

It should be noted that the work plan indicated that surface soil samples would be collected from 0-1 foot bgs. However, conditions in the field warranted surface sampling to 2 feet bgs.

Analytical data for use in the RI/FS from background or reference locations are available for the following media:

- Surface soils;
- Subsurface soils;
- Groundwater;
- River sediment; and
- River surface water.

Figure 3-1 depicts the locations of background soil and groundwater samples collected in the remedial investigation.

Figures 3-2a (Northern Parcel), 3-2b (Southern Parcel), and 3-2c (AOC 19 – Off-site portion of COG Pipeline) depict the locations of individual soil samples evaluated in this HHRA. Figure 3-3 depicts the locations of individual groundwater samples evaluated in this HHRA. Figure 3-4 depicts the locations individual surface water and sediment samples evaluated in this HHRA.

3.2 Data Compilation and Summary Statistics

Analytical data collected in support of the RI/FS have been compiled and tabulated in an EQuIS 5 database for statistical analysis. The analytical data used in the HHRA are presented in Appendix A. The samples used in the HHRA to evaluate each medium and area are presented in Tables 3-1 to 3-5 as follows:

- Table 3-1: Surface soil and Block A Surface Slag;
- Table 3-2: Subsurface soil and Block A Subsurface Slag;
- Table 3-3: Groundwater
- Table 3-4: Sediment
- Table 3-5: Surface Water

Tables of summary statistics have been developed for each medium identified above, that present for each constituent the minimum and maximum detected values, the arithmetic mean, and the frequency of detection. In addition, a screening table is presented for the combined surface and subsurface soil data set (all samples listed in Tables 3-1 and 3-2) as several exposure pathways are based on the combined data set. The screening tables are presented in Appendix B.

The steps used to summarize the data for areas where no new data have been collected since the submission of the draft HHRA in June 2006 are as follows:

<u>Treatment of Non-Detects</u>:

- Summary statistics were not calculated for constituents that were not detected in a particular sample grouping. For any grouping of samples for which there is at least one detected value of a particular constituent, summary statistics are calculated. Constituents that were never detected are further evaluated in the Uncertainty Analysis (Section 7.0).
- Where constituents were detected in some samples and not in others in a particular area/medium, an appropriate statistical technique for dealing with non-detected results was determined based on USEPA guidance for calculating exposure point concentrations (USEPA, 2002b). The guidance presents three methods for handling non-detects:

    1. Simple substitution. In this method, a constant value or fraction of the detection limit (i.e., ½ detection limit) is used as a proxy concentration.
    2. Bounding methods. This method is used to determine the upper and lower bounds of the UCL based on the full range of possible values for the detection limit, and is not based on the distribution of the data. If bounding indicates that the effects of the non-detects are negligible, no further analysis is required.
    3. Distributional methods. This method relies on the assumption that the shape of the distribution of the non-detects is similar to that of the detected concentrations, and derives proxy concentrations based on that distribution.

Simple substitution was applied in this case. For non-detects for which ½ the SQL was calculated, ½ the sample quantitation limit (SQL) was compared to the maximum detected concentration for that area and medium. Where ½ the SQL was greater than the maximum detected concentration in a particular area/medium, the SQL value was not used in the calculation of summary statistics for that chemical in that area and medium (USEPA, 1989). Due to the sample size, a more statistical method to evaluate results reported as not detected was not used in this COPC screening. An evaluation of detection limits for constituents that were never detected relative to the risk-based screening levels used to select COPCs is provided in the Uncertainty Analysis (Section 7.1.1).

The use of simple substitution of ½ the SQL as a proxy concentration for censored data is increasingly recognized as a statistical method that may not perform well. Recent guidance published by USEPA (USEPA, 2006c) and the most recent version of USEPA's ProUCL software Version 4.0 (USEPA, 2007a,b) recommends alternate and more robust methods for handling censored data in calculating summary statistics, including UCLs. However, a comparison of a subset of UCLs calculated using simple substitution of ½ SQL with UCLs calculated using alternate methods for handling censored data, specifically those provided in the ProUCL Version 4.0, revealed similar concentrations for most cases. Thus, use of simple substitution appears to be a reasonable approach for this risk assessment, and use of alternate methods for handling censored data is not expected to result in appreciably different risk results. The uncertainty associated with using simple substitution and the potential effect on risk assessment results is also discussed in the Uncertainty Analysis (Section 7.3.2 Estimation of Exposure Point Concentrations).

Justification for the above is based in part on comparison of 95 UCL concentrations for key COCs at the ARMCO site calculated using: 1) the simple substitution method along with ProUCL Version 3.0 (the method used in the draft HHRA), and 2) ProUCL Version 4.0, which has incorporated various methods for handling censored data in the UCL calculation process (e.g., Kaplan Meier (KM) method, bootstrap method). Table A-1 of Attachment A to the Response to Comments document presented in Appendix K summarizes the results of this comparison for 12 cases including surface soil, surface and subsurface soil combined, surface water, and sediment. The frequency of detection varies among these 12 cases from as low as 35% to as high as 100%, and as few as 5 samples to as many as 70 samples.

As shown in Appendix K, Table A-1, the two sets of UCLs are the same or similar for eight of the 12 cases. The Version 4.0 UCL is higher for two cases and the Version 3.0 UCL calculated using ½ SQL for non-detect values is higher for two cases. Of the eight cases with a frequency of detection of 74% or less (i.e., the data sets with a higher percentage of censored data), the predicted UCL using Version 3.0 and simple substitution of ½ SQL is the same or higher than the Version 4.0 UCL in seven of the eight cases. In summary, simple substitution of ½ SQL appears to generate UCL concentrations that are similar to UCLs calculated using alternate statistical methods that have been incorporated into ProUCL Version 4.0, including data sets with a higher percentage of censored data. Based on these findings, recalculation of statistics using alternate methods for handling non-detect values is not warranted. The potential impact of using ½ SQLs on exposure point concentrations and risk results is discussed in the Uncertainty Analysis.

Treatment of Duplicates: Data for samples and their field duplicates are averaged before summary statistics are calculated, such that a sample and its duplicate are treated as one sample for calculation of summary statistics (including maximum detection and frequency of detection).

Frequency of Detection: The frequency of detection is reported as a ratio and a percentage, and is based on the number of samples reported as detected for a specific constituent and the number of samples used to calculate statistics. The number of samples used to calculate statistics reflects the treatment of non-detects described above.

Minimum Detected Concentration: This is the minimum detected concentration for each constituent/area/medium combination, after duplicates have been averaged.

Maximum Detected Concentration: This is the maximum detected concentration for each constituent/area/medium combination, after duplicates have been averaged.

Mean (Average) Concentration: This is the arithmetic mean concentration for each constituent/area/medium combination, after duplicates have been averaged and non-detects have been evaluated.

For groundwater, these summary statistics were calculated on a well-by-well basis. For the other media, summary statistics were calculated for the exposure areas discussed in Section 5.3.

After submission of the draft HHRA in 2006, additional data have been collected in the upland, riparian and river areas of the Site:

- soil samples from AOC 1, AOC 13, and the Southern Parcel;
- hydric soil samples from a new area, referred to as AOC 22 or the Riparian Area, which runs parallel to the Great Miami River and the Site;
- sediment samples from the Great Miami River; and
- groundwater samples from existing and new wells.

The steps used to summarize these data are as follows:

Treatment of Nondetects: Full SQLs were entered into ProUCL Version 4.002. The software determines the appropriate substitution method. The use of ProUCL is further discussed in Section 5.6.2.

Treatment of Duplicates: Data for samples and their duplicates were averaged before summary statistics were calculated, such that a sample and its duplicate were treated as one sample for calculation of summary statistics (including maximum detection and frequency of detection). Where both the sample and the duplicate were not detected, the resulting value is the average of the detection limits. Where both the sample and the duplicate were detected, the resulting value is the average of the detected results. Where one of the pair was reported as not detected and the other was detected, the detected concentration was used.

Frequency of Detection: The frequency of detection is based on the number of samples reported as detected for a specific constituent and the number of samples used to calculate statistics. The number of samples used to calculate statistics reflects the treatment of non-detects described above.

Maximum Detected Concentration: This is the maximum detected concentration for each constituent, after duplicates have been averaged as described above.

Minimum Detected Concentration: This is the minimum detected concentration for each constituent, after duplicates have been averaged as described above.

Mean of Detected Concentrations: This is the arithmetic mean concentration for each constituent, after duplicates have been averaged. Only detected results are included in the calculation of the mean.

3.3 Selection of Constituents of Potential Concern

COPCs are a subset of the complete set of constituents detected in media that are carried through the quantitative risk assessment process. Selection of COPCs focuses the analysis on the most likely risk "drivers." As stated in USEPA guidance (USEPA, 1993a):

> "Most risk assessments are dominated by a few compounds and a few routes of exposure. Inclusion of all detected compounds at a site in the risk assessment has minimal influence on the total risk. Moreover, quantitative risk calculations using data from environmental media that may contain compounds present at concentrations too low to adversely affect public health have no effect on the overall risk estimate for the site. The use of a toxicity screen allows the risk assessment to focus on the compounds and media that may make significant contributions to overall risk."

Therefore, COPCs have been identified by comparing constituent-specific analytical data for environmental media to appropriate screening levels and conducting a quantitative risk assessment for those constituents detected in an environmental medium in excess of the screening levels described below. Several factors are typically considered in identifying COPCs, including background, frequency of detection, and toxicity, including essential nutrient status. Risk calculations are conducted for the COPCs identified in this step.

The steps to be used to identify COPCs are presented below. The steps were conducted in sequential order, such that a constituent that meets the requirements of a given step was eliminated as a COPC and was not evaluated in subsequent steps. Appendix B presents the screening tables for each medium.

3.3.1 Frequency of Detection

A frequency of detection screen was conducted for surface soil, surface and subsurface soil combined (which is evaluated for the future construction worker), sediment, and surface water. Because groundwater was evaluated on a well-by-well basis, no frequency of detection screen was conducted. Constituents that were detected in fewer than 5% of samples, provided at least 20 samples are available, were considered for elimination as COPCs on the basis of low frequency of detection. Consideration was given to whether detection limits for non-detect results achieved risk-based screening levels. Only two constituents in one medium were eliminated on the basis of low frequency of detection, as indicated below:

- 2-methylphenol in AOC 13 combined surface and subsurface soil (detected in 2 of 48 samples; detection limits are not elevated above screening value);
- 2,4-dimethylphenol in AOC 13 combined surface and subsurface soil (detected in 2 of 48 samples; detection limits are not elevated above screening value);

Three additional constituents were detected in fewer than 5% of samples in combined surface and subsurface soil (thallium in AOC 1, thallium in AOC 19, and PCBs in AOC 18 & 21). However, these constituents were identified as COPCs in surface soil. Therefore, these three constituents were retained as COPCs for combined surface and subsurface soil.

3.3.2 Comparison to Risk-Based Screening Levels

A risk-based screen was performed to identify COPCs in each medium. The methods and screening level sources for each medium are described below. An evaluation of the potential for vapor intrusion from groundwater-to-indoor air was also conducted, following guidance from USEPA (2002b). The maximum detected concentration was used in the comparisons. For groundwater, the maximum detected concentration in each well was used.

Soil, Slag, and Sediment

USEPA Region 9 Preliminary Remediation Goals (PRGs) for residential soil (USEPA, 2004b) were used to identify COPCs in soil, slag, and sediment. PRGs are risk-based concentrations in soil corresponding to a cancer risk level of $1x10^{-6}$ and a hazard index of one. To account for potential additive effects on the same target organ, for PRGs based on non-cancer effects, the screening value used is the non-cancer PRG divided by ten. PRGs for residential soil assume daily contact by an adult and a child and assume incidental ingestion, dermal contact, and inhalation of soil derived dusts and vapors. PRGs are not intended to represent "de facto" cleanup standards but rather are screening levels that help determine whether further evaluation is necessary for a particular constituent at a particular location (USEPA, 2004b).

If no PRG is available, a value was assigned to evaluate the constituent using a PRG from a structurally similar constituent. For soil/sediment, the following structural surrogates were used due to lack of a Region 9 PRG:

- 4-methyl-isobutyl ketone for 2-haxanone
- naphthalene for 2-methylnaphthalene
- acenaphthene for acenaphthylene
- pyrene for benzo(ghi)perylene
- anthracene for phenanthrene

Groundwater

The lower of the USEPA Maximum Contaminant Level (MCL) (USEPA, 2004c) and the most current Region 9 PRG for tapwater (USEPA, 2004b) was used to select groundwater COPCs. PRGs for noncarcinogenic constituents were divided by 10 to account for cumulative effects.

If no screening level is available from either of the above sources, a value was assigned to evaluate the constituent using a PRG from a structurally similar constituent. For groundwater, the following structural surrogates were used due to lack of a Region 9 PRG:

- naphthalene for 2-methylnaphthalene
- acenaphthene for acenaphthylene
- pyrene for benzo(ghi)perylene
- anthracene for phenanthrene

Groundwater concentrations were also compared to the screening levels provided in USEPA (2002b) to identify volatile COPCs in groundwater for consideration in the vapor intrusion to indoor air pathway.

Surface Water

For surface water, Ohio drinking water quality criteria for the Ohio River Drainage Basin were used where available (OAC 3745-1-34. Drinking water values). Where Ohio criteria were not available, the human health ambient water quality criteria (HHAWQCs) were used (value for water and organisms) (USEPA, 2006b). These criteria are derived to be protective of surface waters used for drinking water and fishing. When a HHAWQC was not available, the lower of the MCL and the most current Region 9 tap water PRG was used.

3.3.3 Essential Nutrients Screening

Essential nutrients are defined as calcium, iron, magnesium, sodium, and potassium (USEPA, 1989). Essential nutrients are typically not included in quantitative HHRAs, because they are toxic only at very high concentrations not found at most hazardous waste sites. Thus, calcium, magnesium, sodium, and potassium were not included as COPCs. Iron was evaluated in each medium on a case-by-case basis, because of the existence of an oral reference dose for this essential nutrient. Comparison with a toxicity-based screening value was considered in determining whether iron should be identified as a COPC.

3.3.4 Comparison to Background

Upgradient and other background samples collected in the vicinity of the Site provide information on levels of constituents typical for various media in the local area. In accordance with the Work Plan (ENSR, 2005), site conditions are compared to local background conditions to determine whether or not concentrations of constituents are representative of or consistent with background concentrations, in which case they are not included in risk calculations. At the request of USEPA, consideration of background was not included in the upfront COPC selection process. Rather, consistency with background was considered in the Uncertainty Analysis and determination of final COCs. Background samples are listed in Table 3-6.

3.3.5 Summary

Based on the above three screening steps (excluding comparison to background, the COPCs selected for inclusion in the quantitative HHRA are summarized in the following tables:

- Table 3-7: Surface Soil;
- Table 3-8: Combined Surface and Subsurface Soil
- Table 3-9: On-Site Groundwater (volatile COPCs for the vapor intrusion pathway are noted);
- Table 3-10: Off-Site Groundwater at Hamilton North Wellfield (using on-site intermediate and deep groundwater to conservatively estimate concentrations at the Hamilton North well – see section 5.6 for discussion);
- Table 3-11: Sediment
- Table 3-12: Surface Water

Table 3-13 presents the full list of COPCs in all media evaluated in this Baseline HHRA. Appendix B presents the COPC screening tables and screening criteria for each medium.

4.0 Dose Response Assessment

The purpose of the dose-response assessment is to identify the types of adverse health effects a constituent may potentially cause, and to define the relationship between the dose of a constituent and the likelihood or magnitude of an adverse effect (response) (USEPA, 1989). Adverse effects are classified by USEPA as potentially carcinogenic or noncarcinogenic (i.e., potential effects other than cancer). Dose-response relationships are defined by USEPA for oral exposure and for exposure by inhalation. Oral toxicity values are also used to assess dermal exposures, with appropriate adjustments, because USEPA has not yet developed values for this route of exposure. Combining the results of the toxicity assessment with information on the magnitude of potential human exposure provides an estimate of potential risk.

Numerical toxicity values are generally obtained from USEPA databases/sources. The dose-response relationship is often determined from laboratory studies conducted under controlled conditions with laboratory animals. These laboratory studies are controlled to minimize responses due to confounding variables, and are conducted at relatively high dose levels to ensure that responses can be observed using as few animals as possible in the experiments. Humans are typically exposed to constituents in the environment at levels much lower than those tested in animals. Mathematical models or uncertainty factors are used to extrapolate the relatively high doses administered to animals to predict potential human responses at dose levels far below those tested in animals. The low doses encountered in the environment may be detoxified or rendered inactive by the myriad of protective mechanisms that are present in humans (Ames et al., 1987), resulting in risk estimates that may overestimate potential health effects in humans. Therefore, the results of these animal studies may only be of limited use in accurately predicting a dose-response relationship in humans. However, to be protective of human health, USEPA incorporates many conservative assumptions and safety factors when deriving numerical toxicity criteria from laboratory studies, as discussed below.

This section contains seven subsections. Section 4.1 describes the sources of dose-response values. Section 4.2 describes USEPA's approach for developing noncarcinogenic dose-response values. Section 4.3 describes the dose-response values developed by USEPA for the evaluation of potential carcinogenic effects. Section 4.4 describes the method used to evaluate dermal absorption of constituents in soil and sediment. Sections 4.5, 4.6, 4.7, and 4-8 discuss dose-response issues related to PCBs, dioxins/furans, mercury, and lead, respectively.

4.1 Sources of Dose-Response Values

The USEPA's guidance regarding the hierarchy of sources of human health dose-response values in risk assessment was followed (USEPA, 2003). Sources of the published dose-response values in this risk assessment include:

- Tier 1: USEPA's Integrated Risk Information System (IRIS) (USEPA, 2008a),
- Tier 2: Provisional Peer-Reviewed Toxicity Values (PPRTVs) obtained from USEPA via the USEPA National Center for Environmental Assessment (NCEA) in Cincinnati, Ohio,
- Tier 3: California EPA's Office of Environmental Health and Hazard Assessment (OEHHA) (CalEPA 2005, 2008), Minimal Risk Levels (MRLs) published by the Agency for Toxic Substances and Disease Registry (ATSDR, 2007), and the Health Effects Assessment Summary Tables (HEAST) (USEPA, 1997b).

The primary (Tier 1) USEPA source of dose-response values is IRIS, an on-line computer database of toxicological information (USEPA, 2008a). The IRIS database is updated monthly to provide the most current USEPA verified dose-response values. As defined by the USEPA (1997b), a dose-response value is "Work

Group-Verified" if all available information on the value has been examined by an Agency Work Group, the value has been calculated using current Work Group methodology, a unanimous consensus has been reached on the value by the Work Group, and the value appears on IRIS.

When a dose-response value is not available from IRIS, PPRTVs or other provisional values published by the USEPA NCEA in Cincinnati were used (Tier 2). The NCEA generally provides a toxicological summary for the value. A request was submitted to USEPA for PPRTVs on June 5, 2008. PPRTV position papers were provided by USEPA on June 24, 2008 for aluminum, iron, dibenzofuran, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, and indeno(1,2,3-cd)pyrene. USEPA indicated that PPRTVs were not available for antimony, cadmium, benzo(a)pyrene, dibenzo(a,h)anthracene, or vanadium.

Where Tier 1 or Tier 2 values were not available, Tier 3 sources including the California EPA Office of Environmental Health and Hazard Assessment (OEHHA) (CalEPA, 2005, 2008) and MRLs (ATSDR, 2005) were consulted.

If dose-response values were not available from any of the above sources, dose-response values were obtained from USEPA's HEAST (USEPA, 1997b). HEAST was formerly published annually by the USEPA and provides a compilation of dose-response values available at the time of publishing. Because HEAST is no longer updated regularly, the dose-response values provided may not represent the most current values available and are considered Tier 3 values. In addition, the dose-response values provided by HEAST are considered to be provisional, i.e., the value has had some form of agency review, but does not appear on IRIS. The HEAST values may or may not have been generated through the Agency Work Group process, but the values generally use all available information, use current methodology, and a consensus was reached by Agency scientists on the value. HEAST is, therefore, considered to be an unverified source of dose-response values and is used only if no dose-response value is available from IRIS or the NCEA. Therefore, the hierarchy of dose-response value sources correlates in general with the level of confidence in the values, with the values directly provided by HEAST having the least level of confidence.

4.2 Noncarcinogenic Dose-Response Assessment

Constituents with known or potential noncarcinogenic effects are assumed to have a dose below which no adverse effect occurs or, conversely, above which an adverse effect may be seen. This dose is called the threshold dose. A conservative estimate of the true threshold dose is called a No Observed Adverse Effect Level (NOAEL). The lowest dose at which an adverse effect has been observed is called a Lowest Observed Adverse Effect Level (LOAEL). By applying uncertainty factors to the NOAEL or the LOAEL, Reference Doses (RfDs) for chronic exposure to constituents with noncarcinogenic effects have been developed by USEPA (1997b, 2004b, 2008).

In regulatory toxicity assessment, USEPA assumes that humans are as sensitive, or more sensitive, to the toxic effects of a constituent as the most sensitive species used in the laboratory studies. Moreover, the RfD is developed based on the most sensitive or critical adverse health effect observed in the study population, with the assumption that if the most critical effect is prevented, then other potential toxic effects are prevented. Uncertainty factors are applied to the NOAEL (or LOAEL, when a NOAEL is unavailable) for this critical effect to account for uncertainties associated with the dose-response relationship. These include using an animal study to derive a human dose-response value, extrapolating from a LOAEL to a NOAEL, extrapolating from a subchronic (partial lifetime) to a chronic lifetime exposure, and evaluating sensitive subpopulations. Generally, a 10-fold factor is used to account for each of these uncertainties; thus, the total uncertainty factor can range from 10 to 10,000. In addition, an uncertainty factor or a modifying factor of up to 10 can be used to account for inadequacies in the database or other uncertainties. The resulting RfDs are very conservative, i.e., health protective, because of the use of the large uncertainty factors. For constituents with noncarcinogenic effects, an RfD provides reasonable certainty that no noncarcinogenic health effects are expected to occur even if daily exposures were to occur at the RfD level for a lifetime. RfDs and exposure doses are expressed in units of milligrams of constituent per kilogram of body weight per day (mg/kg-day). The lower the RfD value, the lower is the assumed threshold for effects, and the greater the assumed toxicity.

In identifying the appropriate RfD, the duration of exposure was considered. Chronic dose-response values apply to exposures lasting greater than seven years, while subchronic dose-response values apply to exposures lasting fewer than seven years (USEPA, 1989). Therefore, for evaluation of the future construction worker whose exposure is assumed to last one year, subchronic dose-response values were used. Subchronic dose-response data are not available for every compound for which a chronic dose-response value has been derived. For a COPC lacking a subchronic RfD or for which a subchronic RfD could not be derived by removal of the applied subchronic-to-chronic extrapolation uncertainty factor, the chronic dose-response value was used. NCEA and HEAST (1997b) provided a number of subchronic dose-response values, which are not available on IRIS.

Tables 4-1 and 4-2 summarize chronic dose-response information for COPCs with potential noncarcinogenic effects for the oral and inhalation routes of exposure, respectively. Tables 4-3 and 4-4 summarize subchronic dose-response information for the oral and inhalation routes of exposure, respectively. For each COPC, the chemical abstracts service number (CAS number), the dose-response value (RfD), and the reference for the dose-response value are presented. In addition, the USEPA confidence level in the value, the uncertainty factor, the modifying factor, the study animal, study method, target organ and critical effect upon which the dose-response value is based are also presented for each COPC, where available. The confidence level is provided for constituents published on IRIS, and is based on the confidence in the study and the extent of toxicity information available for that constituent. Adjustments for dermal absorption are discussed in Section 4.4. For inhalation dose-response values, the inhalation reference concentration (RfC) is also presented, where available. Inhalation RfCs were converted to inhalation RfDs assuming a 70 kilogram adult inhales 20 m^3 per day.

4.3 Carcinogenic Dose-Response Assessment

USEPA has developed new carcinogen risk assessment guidelines (USEPA, 2005a) that revise and replace the previous carcinogen risk assessment guidelines. However, the carcinogen risk assessments for many of the constituents listed in USEPA's IRIS database still follow the classification system developed in the previous guidance (USEPA, 1999a). The classification system in the previous guidance was developed according to the weight of evidence from epidemiologic and animal studies:

Group A - Human Carcinogen (sufficient evidence of carcinogenicity in humans)

Group B - Probable Human Carcinogen (B1 - limited evidence of carcinogenicity in humans; B2 - sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans)

Group C - Possible Human Carcinogen (limited evidence of carcinogenicity in animals and inadequate or lack of human data)

Group D - Not Classifiable as to Human Carcinogenicity (inadequate or no evidence)

Group E - Evidence of Noncarcinogenicity for Humans (no evidence of carcinogenicity in adequate studies)

In the previous guidance, it was assumed that there is some finite level of risk associated with each non-zero dose. The USEPA has developed computerized models that extrapolate dose-response relations observed at the relatively high doses used in animal studies to the low dose levels encountered by humans in environmental situations. The mathematical models developed by USEPA assume no threshold, and use both animal and human data (where available) to develop a potency estimate for a given constituent. The potency estimate, called a cancer slope factor (CSF) is expressed in units of $(mg/kg\text{-}day)^{-1}$; the higher the CSF, the greater the carcinogenic potential.

USEPA (2005a) places greater emphasis on critically evaluating available data from which a default option may be invoked if needed in the absence of critical information. The guidance also emphasizes the use of mode of action data. Mode of action is defined as a sequence of key events and processes, starting with interaction of an agent with a cell and resulting in cancer formation. Some modes of action are anticipated to be mutagenic and are assessed with a linear approach. Other modes of action may be modeled with either linear or nonlinear approaches after a rigorous analysis of available data under the guidance provided in the framework for mode of action analysis. USEPA (2005a) uses a weight of evidence narrative rather than the classification system that was used in the previous guidance. The following descriptors are recommended along with the weight of evidence narrative:

- Carcinogenic to humans – this descriptor indicates strong evidence of human carcinogenicity.
- Likely to be carcinogenic to humans – this descriptor is appropriate when the weight of evidence is adequate to demonstrate carcinogenic potential to humans.
- Suggestive evidence of carcinogenic potential – this descriptor is appropriate when the weight of evidence is suggestive of carcinogenicity; a concern for potential carcinogenic effects in humans is raised, but the data are judged not sufficient for a stronger conclusion.
- Inadequate information to assess carcinogenic potential – this descriptor is appropriate when available data are judged inadequate for applying one of the other descriptors.
- Not likely to be carcinogenic to humans – this descriptor is appropriate when the available data are considered robust for deciding that there is no basis for human hazard concern.

More than one descriptor can be used when a constituent's effects differ by dose or exposure route.

Table 4-5 summarizes the dose-response information for COPCs classified by the USEPA as potential carcinogens for the oral route of exposure, and Table 4-6 provides this information for COPCs classified as potential carcinogens for the inhalation route of exposure. For each constituent, the CAS number, USEPA carcinogenicity class, the oral cancer-slope factor and the reference are provided. In addition, the study animal and route of exposure upon which the CSF is based are presented. Adjustments for dermal absorption are discussed in Section 4.4.

4.4 Dermal Absorption

As there are no dermal dose-response values, oral dose-response values are used to evaluate dermal exposures. The equation for calculating dermal absorption gives rise to an absorbed dose, making it necessary to adjust the oral toxicity factor to account for an absorbed rather than an administered dose. This adjustment accounts for the absorption efficiency in the critical study, which forms the basis of the RfD or CSF. For example, in the case where oral absorption in the critical study is essentially complete (i.e., 100%), the absorbed dose is equivalent to the administered dose, and therefore no adjustment is necessary. USEPA (2004a, Exhibit 4-1) provides recommended adjustment factors for oral dose-response values. For organic constituents, no adjustment is considered necessary, since their gastrointestinal absorption is generally high. As indicated in Tables 4-1, 4-3, and 4-5, USEPA (2004a) recommends gastrointestinal absorption adjustments for a number of the COPCs evaluated in this HHRA (i.e., inorganics).

The next step is to determine dermal absorption fractions for COPCs in soil. The dermal absorption fraction (DAF) accounts for lower absorption through the skin. USEPA (2004a) provides constituent-specific dermal absorption fractions for a limited number of constituents. Where DAFs are not available from USEPA (2004a), the default values of 0.01 (1.0 %) for organic constituents and 0.001 (0.1 %) for inorganic constituents recommended by USEPA Region 4 (2000a) were used. Table 4-7 shows the dermal absorption fractions for each of the COPCs.

4.5 PCB Dose-Response

The biphenyl structure of PCBs consists of two aromatic 6-member rings connected by a single bond. There are five locations on each ring that can be chlorinated, and there are 209 individual PCB congeners, each identified by a unique congener number. Structurally, PCB congeners can be classified into groups based on the number of chlorines per molecule (e.g., monochloro-, dichloro-, trichloro-, up to decachloro-biphenyl). These groups are referred to as homologs.

Aroclor mixtures are the commercial mixtures of PCBs that were used in industry. The Aroclors are identified numerically (e.g., Aroclor 1260, Aroclor 1016). The higher the Aroclor number, the more enriched is the mixture in congeners containing higher numbers of chlorines. Each Aroclor mixture exhibits a characteristic, however overlapping, range of congeners, and Aroclors are identified and quantitated in samples by comparing the sample results to Aroclor standards. Total PCBs in a sample can be calculated by summing the Aroclor concentrations.

Risks from potential exposures to PCBs have been calculated using the most current guidance available from USEPA. Currently, USEPA-approved guidance is provided in IRIS (USEPA, 2008a). Total PCB concentrations were calculated by summing individual Aroclor concentrations for Aroclors detected at least once in a medium. The total PCB concentrations were used to calculate the PCB exposure dose to be combined with the verified cancer slope factors listed in IRIS (USEPA, 2008a). Guidance provided in IRIS specifies three tiers of human slope factors for environmental PCBs: high risk and persistence, low risk and persistence, and lowest risk and persistence. The choice of slope factors for use depends on the route and medium of exposure and PCB chlorine content, as outlined in IRIS (USEPA, 2006). These values are presented in Table 4-8. Based on a review of the CSF selection criteria, the CSF value of 2 $(mg/kg\text{-}day)^{-1}$ was used in this HHRA for all exposure routes.

Non-cancer chronic risks from potential exposures to PCBs were calculated using the most conservative RfD for a PCB mixture, the oral reference dose for Aroclor 1254 of 2E-05 mg/kg-day.

4.6 Dioxin Dose-Response

The potential noncarcinogenic and carcinogenic effects associated with exposure to dioxin and furan congeners in environmental media were assessed in accordance with the approach developed by USEPA as follows. Risks were calculated for 2,3,7,8-tetrachloro-dibenzo-p-dioxin (2,3,7,8-TCDD) and the dioxin and furan congeners using the cancer slope factor for 2,3,7,8-TCDD listed in HEAST and using the toxic equivalency factors (TEFs) provided by World Health Organization (WHO) (Van den Berg et al., 1998). The TEFs are fractions that equate the potential toxicity of each congener to that of 2,3,7,8-TCDD. The TEFs are listed in Table 4-9. For each sample, the reported sample concentration (or half or full detection limit, as appropriate, for non-detected congeners) for each dioxin and furan congener having a TEF listed by WHO was multiplied by its TEF, resulting in a TCDD toxic equivalence concentration (TCDD-TEQ). The TCDD-TEQ values for each of the congeners were then added together for each sample and treated as one sample concentration in the risk assessment. The cancer slope factor (USEPA, 2008a) for 2,3,7,8-TCDD was used to calculate potential carcinogenic risks resulting from potential exposure to 2,3,7,8-TCDD-TEQs. The MRL (ATSDR, 2007) for 2,3,7,8-TCDD of 1E-09 mg/kg-day was used to estimate noncarcinogenic risks, which is consistent with the USEPA's current estimated average dose to the U.S. population (~1 pgTEQ/kg/day) (USEPA, 2003c).

4.7 Mercury Dose-Response

Mercury was identified as a COPC in soil and surface water. The reference dose for mercuric chloride was used to evaluate the soil and surface water pathways. Because mercury was identified as a COPC in surface water, potential exposure to mercury in fish tissue was also evaluated. Because the Ohio water quality criteria for mercury are based on methyl mercury, the bioconcentration factor (BCF) for methyl mercury was used to estimate concentrations of mercury in fish tissue based on the surface water concentrations. Therefore, the reference dose for methyl mercury was used to evaluate the fish tissue pathway.

4.8 Lead Dose-Response

Because of the uncertainties in the dose-response relationship between exposure to lead and biological effects, it is unclear whether the noncarcinogenic effects of lead exhibit a threshold response. Therefore, an RfD for lead is not available. Although USEPA has classified lead as a B2 (probable human) carcinogen, no cancer slope factor (CSF) has been developed. Therefore, potential exposures to lead cannot be evaluated using the traditional methods of risk assessment.

The USEPA Integrated Exposure Uptake Biokinetic (IEUBK) Model was used to assess exposure to lead in soil and groundwater for the residential scenario. To evaluate soil lead exposure for nonresidential scenarios, the Adult Lead Model was used (USEPA, 1996c, spreadsheet version date 5/19/03). The model draws on two main sources in its derivation, Bowers et al. (1994) and USEPA (1996c). The model assumes that there is a baseline blood lead level in the adult population of the United States. It assumes that there is a relationship between uptake of lead into the body and blood lead levels. A numerical value, called a biokinetic slope factor, was assigned to represent the relationship between uptake of lead into the body and blood levels. The model assumes a target blood lead level of concern is 10 ug/dL (micrograms per deciliter), and calculates a soil concentration corresponding to that level. These models are described in greater detail in Appendix C.

5.0 Exposure Assessment

The purpose of the exposure assessment is to predict the magnitude and frequency of potential human exposure to each of the COPCs retained for quantitative evaluation in the HHRA. The first step in the exposure assessment process is the characterization of the setting of the Site and surrounding area. Current and potential future Site uses and potential receptors (i.e., people who may contact the impacted environmental media of interest) are then identified. Potential exposure scenarios appropriate to current and potential future Site uses and receptors are then developed. Those potential exposure pathways for which COPCs are identified and are judged to be complete were evaluated quantitatively in the risk assessment.

This section includes the following subsections: Section 5.1 presents the conceptual site model (CSM) for the Site; Section 5.2 discusses exposure scenarios and the receptors for the Site; Section 5.3 discusses exposure areas; Section 5.4 presents the receptor-specific exposure parameters; Section 5.5 presents the methods for quantifying potential exposures; and Section 5.6 discusses the identification of exposure points and exposure point concentrations.

5.1 Conceptual Site Model

A preliminary conceptual site model (CSM) was presented in the Remedial Investigation/Feasibility Study Support Sampling Plan (Revision 3) (ENSR, 2005). That model, updated based on information collected in the RI/FS investigation, is presented in this section. A schematic of the CSM is presented in Figure 5-1.

As described in the Remedial Investigation/Feasibility Study Support Sampling Plan (Revision 3), the Site consists of the southern parcel and the northern parcel (totaling 252 acres), both vacant. The southern parcel formerly contained the Hamilton Coke Plant (HCP), two blast furnaces for ore making, a sinter plant, and associated coal handling facilities. Very little evidence remains of the HCP and the blast furnace area, which were decommissioned/ demolished in 1988-89 and 1993-95, respectively. The roadway through the property remains and a large hilly area exists on the western side of the property where the blast furnaces were located. Some concrete slabs remain, indicating where buildings and a large gas collector were located. The majority of the Site is covered with tall grass and occasional trees. This parcel is surrounded by a chain-link fence and remains locked. The Great Miami River abuts the southern parcel to the east and south. The majority of the southern parcel lies within the wellhead protection area for the City of Hamilton North Wellfield.

The northern parcel is located north of Augspurger Road and is bounded to the west-northwest by a rail yard operated by CSX Transportation, to the northeast by Jackson Road, to the east-southeast by residential property, and to the south by Augspurger Road. A CSX rail line bisects this parcel, east to west, parallel to Augspurger Road. The portion of the parcel between Augspurger Road and the CSX rail line was used to store coal for the HCP and later for storing air scrubber sludge and dust from the blast furnaces. A former slag processing plant was located on the northwestern portion of the north parcel. No buildings are present at the location of the former slag plant; however, concrete block walls remain in one area and a large demolished concrete structure remains in another area. A closed, fenced landfill is located on the east side of this northern parcel north of the east-west rail line. The closed landfill is approximately 4-5 acres in size, has approximately 3-5 feet of topographic relief and is covered with tall grass. An intermittent stream that discharges to the Great Miami River is located downslope of the landfill. A portion of the northern parcel is fenced.

In addition, the Site includes a former COG pipeline that runs approximately eight miles from the former Hamilton plant to another AK Steel plant in Middletown, Ohio, mostly along railroad tracks. Land use around the Site is mixed and includes a rail yard, woods, other industrial uses, and residential dwellings.

Based on past operations at the Site, there are a number of potential sources of constituents, release mechanisms, and potentially affected environmental media. For purposes of developing a better understanding of potential exposure pathways for human receptors, the primary sources of historical releases to the environment are depicted in Figure 5-1, along with the primary release mechanisms, primary and secondary affected media, potential routes of exposure and potential current and future human receptors. For purposes of this CSM, the various potential source areas associated with the past operations at the Site have been grouped into eight primary sources. The "Former Production Areas" source includes a large number of sources.

Past manufacturing operations may have resulted in direct releases of constituents to soil in the form of spills, leaks, leaching, and runoff. Constituents in surface soil (and excavated/exposed subsurface soil) may subsequently migrate to ambient (outdoor) air via resuspension as windblown dust and/or volatilization. Constituents in surface soil may migrate downward into subsurface soil and ultimately on-site groundwater. Dissolved constituents in groundwater may migrate to off-site groundwater. Constituents may have been released directly to the river via former storm water outfalls and via surface runoff during storm events, potentially impacting sediment and surface water in the river. Bioaccumulatable compounds in the river surface water/sediment may then be taken up by aquatic organisms. Thus, based on available information, the media of interest are:

- Surface soil/slag (0-2 foot below grade)
- Subsurface soil/slag (2-10 feet below grade)
- Hydric soil in the Riparian Area (AOC 22)
- Surface water in the intermittent stream (AOC 7) and the Great Miami River
- Sediment in the intermittent stream (AOC 7) and the Great Miami River
- Groundwater (on-site and off-site)
- Ambient air (particulates, volatiles)

This CSM was used to develop the potential current and future exposure scenarios for evaluation in the HHRA. The exposure scenarios are fully defined in the exposure assessment. This includes developing both a Reasonable Maximum Exposure (RME) scenarios to represent upper bound exposures and risks and Central Tendency Exposure (CTE) scenario to represent more likely or average exposures and risks. RME assumptions were employed in the quantitative risk assessment. CTE assumptions are evaluated in the Uncertainty Analysis (Section 7.0) based on whether potential Site risks were identified above risk targets (i.e., the lower end of USEPA's target cancer risk range of 1×10^{-6} to 1×10^{-4} and/or a non-cancer hazard index of 1 (on a target organ basis).

5.2 Identification of Exposure Scenarios

Based on the CSM presented in Section 5.1 and depicted in Figure 5-1, the potential exposure pathways for human receptors at the Site are as follows:

- Ingestion, dermal contact, and inhalation of on-site surface soil and subsurface soil;
- Ingestion, dermal contact, and inhalation of hydric soil in the Riparian Area (AOC 22);
- Ingestion and dermal contact with sediment and dermal contact with surface water present in the intermittent stream (AOC 7) and the Great Miami River;
- Consumption of fish caught in the Great Miami River, including the portion of the river north of the Site where the former COG pipeline (AOC 19) runs underneath the river;
- Consumption of groundwater as drinking water, and dermal contact with tap water while bathing (for a residential receptor);

- Inhalation of volatiles (vapor intrusion to indoor air).

The future use of the Site will continue to be non-residential (i.e., commercial, industrial), which most likely will be ensured via an institutional control. However, at the request of EPA, a hypothetical future adult and child resident receptor who lives on-site was included in this baseline HHRA. The potential receptors and exposure pathways evaluated in this HHRA are consistent with those identified in the approved RI/FS Work Plan (ENSR, 2005).

A current and future trespasser was evaluated for potential exposure to COPCs in on-site surface soil via ingestion, dermal contact, and inhalation of particulates in outdoor air. The trespasser was also evaluated for potential exposure to surface and subsurface soil COPCs via inhalation of volatiles in outdoor air. The trespasser was also evaluated for potential exposure to COPCs in sediment and surface water in the Great Miami River and the intermittent stream (AOC 7) via ingestion and dermal contact with sediment and dermal contact with surface water.

A current and future recreational angler was evaluated for potential exposure to COPCs in sediment and surface water in the Great Miami River via ingestion and dermal contact for sediment and dermal contact for surface water. The recreational angler was assumed to ingest fish caught in the river. The intermittent stream (AOC 7) does not support a fish population.

A hypothetical future on-site resident (adult and child) was evaluated for potential exposure to COPCs in surface soil via incidental ingestion and dermal contact, and inhalation of particulates in outdoor air. The hypothetical future on-site resident was also evaluated for potential exposure to surface and subsurface soil COPCs via inhalation of volatiles in outdoor air. Additionally, the hypothetical future on-site resident was evaluated for ingestion of groundwater used as drinking water and dermal contact with tap water while bathing. Potential exposure to volatile groundwater COPCs via inhalation (vapor intrusion to indoor air) was also evaluated. Potential exposure via inhalation of volatiles released from groundwater for household tasks is discussed qualitatively in Section 6.3.3.

A current and future off-site resident (adult and child) was evaluated for potential exposure to COPCs in groundwater from the Hamilton North Wellfield via ingestion of groundwater as drinking water and dermal contact with tap water while bathing.

A future construction/utility worker was evaluated for potential exposure to constituents in surface and subsurface soil (ingestion, dermal contact, inhalation of particulates and volatiles). Construction/utility work is assumed to occur to a maximum depth of 10 feet bgs. Depth to groundwater at the Site is greater than 10 feet bgs in the shallow aquifer. Therefore, the construction/utility worker was not evaluated for exposure to COPCs in shallow groundwater. A screening-level analysis was performed to evaluate inhalation of VOCs that may volatilize from shallow groundwater and migrate up through the vadose zone into a trench for a construction/utility worker. The evaluation, which is included in Appendix K, Attachment B, shows that predicted potential carcinogenic risks and noncarcinogenic hazard indices are negligible. Appendix K, Attachment B provides the calculation sheets and description for this screening-level analysis. Therefore, this pathway was not quantitatively evaluated in the HHRA.

A future on-site commercial or industrial worker was evaluated for potential exposure to COPCs in surface soil on-site via ingestion, dermal contact, and inhalation of particulates in outdoor air. Inhalation of volatile surface and subsurface soil COPCs in outdoor air was also evaluated. A second scenario, not discussed in the work plan, in which it is assumed that subsurface soils are brought to the surface, is also evaluated. The on-site worker was also evaluated for potential exposure to COPCs via ingestion of groundwater used as drinking water.

The potential exposure pathways and associated human receptors are presented in Table 5-1.

5.3 Exposure Areas

Specific exposure areas were identified based on the history of Site use and review of Site data. Three primary exposure areas were identified based on the history of use: the northern parcel, the southern parcel, and the former COG pipeline. For soil, sub-areas representing different historical operations and exposure potentials for the receptors described in Section 5.4 were identified:

Northern Parcel

- AOC 1 – Sludge laydown area;
- AOC 2 – Closed landfill;
- AOC 18 and AOC 21 (On-site portion of former COG pipeline and Wooded area);
- AOC 19 (Off-site portion of former COG pipeline); and
- Block A – Slag piles.

Southern Parcel

- All of the Southern Parcel except AOC 13; and
- AOC 13.

Based on a review of Site data, considerably elevated concentrations of a number of COPCs are present in soil and groundwater in AOC 13 relative to the remainder of the Southern Parcel. Therefore, AOC 13 was identified as a potential hot spot and evaluated as a separate exposure area in the risk assessment.

Three exposure areas for surface water and sediment were identified:

- Great Miami River (reach adjacent to the Site);
- Great Miami River (where the former COG pipeline (AOC 19) crosses beneath the river); and
- the intermittent stream (AOC 7).

The Riparian Area between the Site and the Great Miami River (AOC 22) was also identified as a separate exposure area.

Each groundwater well was treated as a separate exposure point (area) for potential drinking water, bathing, and vapor intrusion pathways. This approach was discussed and agreed to by USEPA and OEPA during the June 27, 2006 project conference call.

Figure 5-2 presents the soil, sediment and surface water exposure areas evaluated in the HHRA. Table 5-2 presents a summary of the exposure areas and which receptors are assumed to be exposed to COPCs in each area.

5.4 Receptor Characterization

The following subsections discuss the parameters used to evaluate each of the potential receptors in the HHRA. Both RME and CTE exposure parameters are discussed. RME scenarios were evaluated for each receptor. CTE evaluations were also conducted and are presented in the Uncertainty Analysis section of the HHRA. Exposure parameters for each receptor are presented and referenced in Tables 5-3 to 5-8. Selected exposure parameters are discussed under the receptor headings (Section 5.4.1- to 5.4.6). Soil-to-skin adherence factors are discussed in Section 5.4.7.

5.4.1 Current and Future Trespasser

It is assumed that the current and future trespasser, who is a child of 7 to 16 years of age, is exposed to COPCs in surface soil via incidental ingestion, dermal contact, and inhalation of particulates in outdoor air. The trespasser is also evaluated for surface and subsurface soil exposure via inhalation of volatiles in outdoor air. The trespasser is also assumed to be exposed to COPCs in sediment and surface water via incidental ingestion and dermal contact with sediment and dermal contact with surface water while wading or playing in the intermittent stream and the Great Miami River. The trespasser is also assumed to be exposed to COPCs in hydric soil via incidental ingestion, dermal contact, and inhalation of particulates in outdoor air in the Riparian Area.

Exposure assumptions for the trespasser under the RME and CTE scenarios are shown in Table 5-3. The exposure frequencies for the trespasser (RME: 52 days per year; CTE: 26 days/year) represent 1 day per week (RME) and 1 day per week for the for the 6 warmest months of the year (CTE). The soil ingestion rates (RME: 100 mg/day, CTE: 50 mg/day) are recommended values for adults (USEPA, 1997a). The inhalation rates (RME: 1.2 m^3/hour; CTE: 1 m^3/hour) are the rates for children under 18 years engaged in moderate activities (RME) or light activities (CTE) on a short-term basis (USEPA, 1997a). Surface area and adherence factors are discussed in Section 5.4.7.

5.4.2 Current and Future Recreational Angler

It is assumed that the current and future recreational angler may incidentally contact sediment and surface water in the Great Miami River while fishing, and hydric soil in the Riparian Area. The recreational angler is also assumed to catch and eat fish from the Great Miami River. Certain bioaccumulative constituents in surface water and sediment may accumulate in fish that are subsequently consumed by humans. In surface water, mercury is the only COPC identified as being bioaccumulative. A bioconcentration factor (BCF) from surface water to fish tissue for mercury was identified (USEPA, 1999b). BCFs for iron and vanadium were not found (USEPA, 1999b). For sediment, PCBs have the potential to bioaccumulate from sediment to fish tissue. A biota-sediment accumulation factor (BSAF) for PCBs from sediment to fish tissue was identified (USEPA, 2005b).

The exposure assumptions for the fish ingestion pathway for the RME and CTE receptors are summarized in Table 5-4. An adult angler who fishes along the Great Miami River is evaluated. The fish ingestion rate for the RME scenario is 0.025 kilograms/day (USEPA, 1997a). The CTE scenario fish ingestion rate (0.008 kilograms/day). These values were derived by averaging the values from three population surveys (Section 10.10.3 of EFH) of desirable sportfishing water bodies (Maine, New York and Michigan). As such, these default freshwater fish rates are likely to be overly conservative for the Great Miami River. Based on the fish community survey work performed in September 2007 (EA Engineering, Science and Technology, 2008), the abundance and variety of sportfish species in the Great Miami River are more limited than in the water bodies included in the three angler surveys used to derive EPA's default recreational angler rates. An exposure frequency of 365 days/year is used for the fish ingestion pathway, because the rate is a normalized daily rate (USEPA, 2000a).

The recreational angler is assumed to incidentally ingest and dermally contact sediment and dermally contact surface water in the Great Miami River while fishing. While visiting the river to fish, the angler is also assumed to be exposed to hydric soil in the Riparian Area via incidental ingestion, dermal contact, and inhalation of particulates in outdoor air. The angler is assumed to fish at each of the two river locations evaluated in the HHRA 52 days per year for the RME scenario and 26 days of the year for the CTE scenario. Shoes and pants or waders are assumed to be worn due to the presence of heavy brush along the river bank and the possibility of broken glass in the sediment; however, the clothing may not prevent surface water exposure. Therefore, the angler's hands, forearms, lower legs, and feet are assumed to be exposed to surface water while fishing, and the angler's hands and forearms are assumed to be exposed to hydric soil and sediment while fishing. Body surface area and the sediment adherence factor are discussed in Section 5.4.7.

5.4.3 Hypothetical Future On-Site Resident (Adult and Child)

The hypothetical future on-site resident is assumed to contact COPCs in surface soil via incidental ingestion and dermal contact and via inhalation of particulates in outdoor air. The hypothetical future on-site resident was also evaluated for surface and subsurface soil exposure via inhalation of volatiles in outdoor air. The resident was evaluated for potential exposure to COPCs via ingestion of on-site groundwater used as a source of drinking water, dermal contact during bathing, and for potential exposure to COPCs in indoor air (vapor intrusion from groundwater). Potential exposure via inhalation of volatiles released from groundwater for household tasks is discussed qualitatively in Section 6.3.3.

Because of the differences in activity patterns and sensitivity to potential COPC exposures, two age groups for the resident receptor were evaluated: the child (age 0 to 6 years, 15 kg body weight) and the adult resident (70 kg body weight) (USEPA, 1991a). The child's lower body weight, combined with a higher soil ingestion rate results in a higher dose per kilogram of body weight than for other age groups. This receptor is then the most sensitive to the noncarcinogenic health effects of COPCs and is, therefore, the target receptor for the noncarcinogenic analysis. Because carcinogenic effects are assumed to be additive over a lifetime, it is more conservative to evaluate carcinogenic effects of COPCs over the assumed 30-year period of residence (6 years as a child and 24 years as an adult). Thus, the evaluation of potential carcinogenic effects for the on-site resident is based on the combined doses/risks of the child and adult age groups.

Exposure assumptions for the on-site resident under the RME and CTE scenarios are shown in Table 5-5. The outdoor air inhalation rates for the future resident are: 1.6 m^3/hour (adult RME), 1.2 m^3/hour (child RME), 0.55 m^3/hour (adult CTE) and 0.30 m^3/hour (child CTE). The RME rates are for moderate activity (USEPA, 1997a), while the CTE rates are average daily rates (USEPA, 1997a). The indoor air inhalation rates for the future resident are: 1.0 m^3/hour (adult RME), 0.8 m^3/hour (child RME), 0.55 m^3/hour (adult CTE) and 0.30 m^3/hour (child CTE). The RME rates are derived assuming 8 hours at a resting inhalation rate and the remainder at an inhalation rate for moderate activity (USEPA, 1997a), while the CTE rates are average daily rates (USEPA, 1997a).

RME soil ingestion rates are 100 mg/day for the adult and 200 mg/day for the child resident (USEPA, 1991a). For the CTE receptor, average soil ingestion rates are used: 50 mg/day for the adult and 100 mg/day for the child (USEPA 1997a).

Surface area and adherence factors are discussed in Section 5.4.7.

A meteorological factor was used under the CTE scenario to account for the fraction of the year during which exposure to constituents in soils may occur (Sheehan et al., 1991; USEPA, 1989). It is reasonable to assume that direct contact with soil or intrusive activities will not occur for non-excavation receptors during inclement weather (i.e., when it is raining or snowing, when the ground is wet or frozen, or when snow or ice are covering the ground. This is not to say that residents would not be outdoors on such days, only that the soil would not be available for significant contact. Thus the frequency of contact with potentially impacted soil is adjusted for these site-specific meteorological conditions (USEPA, 1989).

Based on regional temperature and precipitation data (Cincinnati, Ohio) from the National Climatic Data Center (NCDC, 2006), there are 89.7 days per year with precipitation equal to or greater than 0.1 inches and 19.9 days with temperatures equal to or less than 32 degrees F. Subtracting the average number of days with both conditions (3.7), there are 105.9 days with inclement weather. The metrological factor is then calculated (105.9 days / 365 days = 29%), and it is assumed that exposure to soil will not occur for the residential receptor 29% for the assumed days of exposure (exposure frequency) due to weather restrictions.

5.4.4 Current and Future Off-Site Resident (Adult and Child)

Per the RI/FS Work Plan, an off-site resident is assumed to be exposed to groundwater from the Hamilton North Wellfield that is used as drinking water (ENSR, 2005). In addition to the drinking water and dermal contact pathways discussed in the work plan, an additional pathway is included in the risk assessment to evaluate potential concentrations of VOCs in air during showering or bathing. Under pumping conditions, the Hamilton North Wellfield zone of influence extends into the Site (USGS, 2005). Groundwater flow both regionally and on-site is influenced by the Great Miami River, which runs along the southwest perimeter of the Site. Groundwater flows from the northeast to the southwest for both shallow and intermediate groundwater. For shallow groundwater, groundwater channels toward the bend in the river in the northern portion of the Site, and generally flows more towards the west than the intermediate groundwater.

The off-site resident consuming groundwater from the Hamilton North Wellfield was evaluated for potential exposure to COPCs via ingestion of intermediate and deep groundwater as drinking water and dermal contact during showering/bathing, as well as inhalation of VOCs while showering/bathing. The off-site resident is evaluated for both adult and child age groups. The exposure assumptions for the off-site resident are summarized in Table 5-6.

5.4.5 Future Construction/Utility Worker

The primary medium of concern for the future construction worker/utility worker is soil (surface and subsurface). Because depth to groundwater is greater than 10 feet bgs (generally in the range of 20 to 40 feet bgs), construction workers are not expected to contact groundwater during excavation. Therefore, the potential groundwater exposure pathway is not complete and was not evaluated in the risk assessment. The future construction worker is evaluated for potential exposure to COPCs in surface and subsurface soil via ingestion and dermal contact and inhalation of particulates and volatiles. At the request of USEPA, the future construction worker was also evaluated for potential exposure to volatile COPCs in groundwater that may migrate upward through the vadose zone into the excavation trench and subsequently be inhaled. As discussed in Section 5.2, a screening-level analysis of the excavation trench inhalation pathway shows that predicted potential carcinogenic risks and noncarcinogenic hazard indices are negligible. Appendix K, Attachment B provides the calculation sheets and description for this screening-level analysis. Therefore, this pathway was not quantitatively evaluated in the HHRA.

Exposure assumptions for the construction/utility worker under the RME and CTE scenarios are shown in Table 5-7.

The outdoor air inhalation and surface and subsurface soil exposure frequencies for the RME scenario are 130 days per year, equivalent to 5 days per week for 6 months, while the exposure frequencies for the CTE scenario are 40 days per year, equivalent to 5 days per week for 2 months. USEPA (2002b) states that exposure frequency for a construction worker is site-specific. In an example calculation provided in Appendix E (page E-21) of USEPA (2002b), USEPA assumes an exposure period of six months. The assumption of 130 days/year reflects the colder, northern area of the country where the Site is located, and accounts for meteorological factors such as rain, snow and ice that limit construction activities and preclude contact with soil. It should also be noted that the exposure frequency for the construction worker is intended to reflect the number of days per year where the construction worker is involved in soil excavation activities, not necessarily the total number of days on-site.

The inhalation rates for this receptor (RME: 2.5 m^3/hour; CTE: 1.5 m^3/hour) are the rates for heavy and moderate activity for an outdoor worker (USEPA, 1997a). The RME and CTE soil ingestion rates are 330 mg/day (USEPA, 2002d) and 100 mg/day (USEPA, 1991a), respectively. In accordance with EPA guidance for the Adult Lead Model (USEPA, 1996c, spreadsheet version date 5/19/03), the adult resident soil ingestion rate of 100 mg/day is used for the lead soil RME risk characterization (http://www.epa.gov/superfund/lead/almfaq.htm#screening). Surface area and adherence factors are discussed in Section 5.4.7.

5.4.6 Future On-Site Commercial or Industrial Worker

The future on-site commercial or industrial worker is assumed to contact COPCs in surface soil via incidental ingestion and dermal contact, and inhale COPCs via fugitive dusts from the surface soils and volatile constituents from surface and subsurface soil. A second scenario, not discussed in the work plan, in which it is assumed that subsurface soils are brought to the surface is also evaluated. In the second scenario, all soils are treated as surface soils. The future on-site worker was also evaluated for potential exposure to COPCs via ingestion of on-site groundwater used as a source of drinking water.

Exposure assumptions for the commercial or industrial worker under the RME and CTE scenarios are shown in Table 5-8. The outdoor air inhalation rate for the worker (RME scenario) is 2.0 cubic meters/hour (m^3/hour), and is derived using the USEPA's recommended values for outdoor workers involved in short-term exposures (USEPA, 1997a). The RME rate assumes that one-half of the time the worker is performing moderate activities and one-half of the time the worker is performing heavy activities (see Table 5-23 of USEPA, 1997a).

The inhalation rate for this receptor (CTE scenario) is 1 m^3/hour, the inhalation rate for a light activity level (USEPA, 1997). The RME and CTE inhalation rates are higher than the USEPA's (1997a) adult inhalation rate for long-term exposures (13.3 m^3/day, equal to 0.55 m^3/hour).

Soil ingestion rates of 50 mg/day and 30 mg/day were used for the RME and CTE commercial or industrial worker receptors, respectively (USEPA, 1997a).

Surface area and adherence factors are discussed in Section 5.4.7.

5.4.7 Surface Area and Soil to Skin Adherence Factors

It is assumed that while outdoors, receptors will come into dermal contact with soil. Adherence estimates were calculated using the skin surface area data and soil adherence data from USEPA (1997a and 2004e). The methods used to derive the skin surface areas and adherence factors are described below.

Surface Area

For the trespasser, it is assumed that the hands, forearms, and lower legs are exposed for soil (including hydric soil) contact. For contact with sediment, the hands, forearms, lower legs and feet are assumed to be exposed. Table 5-9 presents the 50th percentile surface areas for those body parts for a child aged 7 to 16, based on the average of boys and girls surface area. The 50th percentile values are used because they correlate with the 50th percentile body weight parameter (e.g., 70 kg for adult) recommended by the USEPA (1989). Additionally, these are the surface areas recommended in Exhibit 3-5 of USEPA (2004a). In accordance with USEPA (2004a) the forearm was assumed to be 45% of the total arm surface area, and the lower legs were assumed to be 40% of the lower leg total surface area. The total surface area assumed to be exposed is 3064 cm^2 for soil and 4,033 cm^2 for sediment.

For the recreational angler, it is assumed that hands and forearms are exposed to sediment and hydric soil. Table 5-10 presents the 50th percentile surface areas for those body parts for a recreational fisher. The total surface area assumed to be exposed is 2134 cm^2. For surface water, it is assumed that the angler's feet and lower legs are also exposed, for a total surface area of 5645 cm^2.

For the adult resident, it is assumed that the head, hands, forearms, and lower legs are exposed for soil contact. For the child resident, it is assumed that head, hands, forearms, lower legs, and feet are exposed for soil exposure. As recommended by USEPA (2004a, Exhibit 3-5) the 50th percentile surface area for those body parts for an adult resident is 5,700 cm^2 and the 50th percentile surface area for a child resident is 2,800 cm^2. For the bathing pathway, the 50th percentile total body surface area is used (18,150 cm^2 for the adult and 6,557 cm^2 for the child). These surface areas represent the average of males and females.

It is assumed that construction workers and on-site workers are required to wear shoes and long pants. It is also assumed that the worker wears a long-sleeved shirt and/or coat during the colder months of the year and, at a minimum, a short-sleeved shirt during the warmer months of the year. Gloves are also likely worn in the winter. Therefore, the construction worker and on-site worker receptor's head, hands, and lower arms are conservatively assumed to be exposed for soil contact throughout the year. Table 5-11 presents the surface areas for each of these body parts at the 50th percentile for adults. The total surface area assumed to be exposed is 3,282 cm^2, which is consistent with the value recommended in Exhibit 3-5 of USEPA (2004a) for a commercial/industrial worker.

<u>Adherence Factors</u>

To account for differences in adherence for different parts of the body, an area-weighted adherence factor is calculated using the body part-specific adherence levels presented in Exhibit C-2 of USEPA (2004a). For each receptor, the skin surface area of each exposed body part is multiplied by its body part-specific adherence factor to yield a total mass adhered to that body part. The total masses are then summed for all exposed body parts, and then divided by the total body surface area exposed to derive the area-weighted adherence factor.

Estimates of adherence are derived from the EFH (USEPA, 1997a), which states that: "In consideration of ... the recent data from Kissel [Kissel et al., 1996]..., changes are needed from past USEPA recommendations [USEPA, 1992] which used one adherence value to represent all soils, body parts, and activities. One approach would be to select the activity from Table 6-11 which best represents the exposure scenario of concern and use the corresponding adherence value from Table 6-12."

USEPA (2004a) indicates that adherence factors should be calculated by either selecting a central tendency soil contact activity and a high-end weighted adherence factor, or by selecting a high-end soil contact activity and using the central tendency weighted adherence factor. The guidance also states that using a high-end soil contact activity should not be used with a high-end weighted adherence factor, as this is not consistent with the use of an RME scenario.

From the exposure scenarios presented in Table 6-11 of USEPA (1997a) and the adherence data presented in Exhibit C-2 of USEPA (2004a), the following approach was used to derive adherence factors:

<u>Trespasser</u>

- Soil/Hydric Soil RME and CTE Scenario – High-end soil contact activity (Soccer Players No. 1) used with geometric mean adherence data = 0.05 mg/cm^2
- Sediment RME and CTE Scenario – High-end soil contact activity (Children Playing in Wet Soil) used with geometric mean adherence data = 0.28 mg/cm^2

The calculations for the trespasser are presented in Table 5-9.

<u>Recreational Angler</u>

- Hydric Soil RME and CTE Scenario – High-end soil contact activity (Soccer Players No. 1) used with geometric mean adherence data = 0.05 mg/cm^2
- RME and CTE Sediment Scenario – Adult sediment/wet soil contact activity (Reed Gatherers) used with geometric mean adherence data = 0.30 mg/cm^2

The calculations for the recreational angler are presented in Table 5-10.

Adult Resident

- RME Scenario – High-end soil contact activity (Gardeners) used with geometric mean adherence data = 0.07 mg/cm^2 (consistent with recommendation in Exhibit 3-5 of USEPA, 2004a)

- CTE Scenario – Central tendency soil contact activity (Groundskeepers) used with geometric mean adherence data = 0.01 mg/cm^2 (consistent with recommendation in Exhibit 3-5 of USEPA, 2004a)

Because the recommended values from USEPA (2004a) were used, calculations are not presented.

Child Resident

- RME Soil Scenario - High-end soil contact activity (Children Playing in Wet Soil) used with geometric mean adherence data = 0.2 mg/cm^2 (consistent with recommendation in Exhibit 3-5 of USEPA, 2004a)

- CTE Soil Scenario - Central tendency soil contact activity (Day Care Kids) used with geometric mean adherence data = 0.04 mg/cm^2 (consistent with recommendation in Exhibit 3-5 of USEPA, 2004a)

Because the recommended values from USEPA (2004a) were used, calculations are not presented.

On-Site Worker

In the Supplemental Soil Screening Guidance (USEPA, 2002d), a default adherence factor (of 0.2 mg/cm^2) is assumed for all commercial/industrial worker receptors which is the median (50th percentile) value for all adult workers at commercial and industrial sites. Use of the receptor/activity-specific approach presented in this report also results in an adherence factor of 0.2 mg/cm^2 for the RME scenario.

- RME Soil Scenario – High-end soil contact activity (Utility Workers) used with geometric mean adherence data = 0.2 mg/cm^2 (consistent with recommendation in Exhibit 3-5 of USEPA, 2004a)

- CTE Soil Scenario – Central tendency soil contact activity (Groundskeepers) used with geometric mean adherence data = 0.02 mg/cm^2 (consistent with recommendation in Exhibit 3-5 of USEPA, 2004a)

Construction Worker

In the Supplemental Soil Screening Guidance (USEPA, 2002d), a default adherence factor (of 0.3 mg/cm^2) is assumed for construction workers. Use of the receptor/activity-specific approach presented in this report also results in an adherence factor of 0.25 mg/cm^2, which has been rounded up to 0.3 mg/cm^2. The calculations for the construction worker are presented in Table 5-11.

5.5 Quantification of Potential Exposures

To estimate the potential risk to human health that may be posed by the presence of COPCs at the Site, it is first necessary to estimate the potential exposure dose of each COPC. The exposure dose is estimated for each COPC via each exposure pathway by which the receptor is assumed to be exposed. Exposure dose equations combine the estimates of COPC concentration in the environmental medium of interest with assumptions regarding the type and magnitude of each receptor's potential exposure to provide a numerical estimate of the exposure dose. The exposure dose is defined as the amount of COPC taken into the receptor and is expressed in units of milligrams of COPC per kilogram of body weight per day (mg/kg-day).

Exposure doses are defined differently for potential carcinogenic and noncarcinogenic effects. The Chronic Average Daily Dose (CADD) is used to estimate a receptor's potential intake from exposure to a COPC with noncarcinogenic effects. According to USEPA (1989), the CADD should be calculated by averaging the dose over the period of time for which the receptor is assumed to be exposed. Therefore, the averaging period is the same as the exposure duration. For COPC with potential carcinogenic effects, however, the Lifetime Average Daily Dose (LADD) is employed to estimate potential exposures. In accordance with USEPA (1989) guidance, the LADD is calculated by averaging exposure over the receptor's assumed lifetime (70 years). Therefore, the averaging period is the same as the receptor's assumed lifetime. The standardized equations for estimating a receptor's daily intake (both lifetime and chronic) are presented below, followed by descriptions of receptor-specific exposure parameters and constituent-specific parameters. The daily intake calculations are presented in Appendix D.

5.5.1 Estimating Potential Exposure to COPCs in Soil or Sediment

Both incidental ingestion of, and dermal contact with, soil or sediment are assumed to occur for several receptors. The following equations are used to calculate the estimated exposure.

Daily Intake (Lifetime and Chronic) Following Incidental Ingestion of Soil or Sediment (mg/kg-day):

$$\text{Daily Intake} = \frac{CS \times SIR \times EF \times ED \times CF}{BW x AT}$$

where:

CS = Soil or Sediment Concentration (mg/kg soil)

SIR = Soil or Sediment Ingestion Rate (mg soil/day)

EF = Exposure Frequency (days/year)

ED = Exposure Duration (year)

CF = Unit Conversion Factor (kg soil or sediment /10^6 mg soil or sediment)

BW = Body Weight (kg)

AT = Averaging Time (days)

Daily Intake (Lifetime and Chronic) Following Dermal Contact with Soil or Sediment (mg/kg-day):

$$DAD = \frac{DA_{event} \times EF \times ED \times EV x SA}{BW x AT} \qquad DA_{event} = CS x CF x AF x ABS_d$$

where:

DAD = Dermal Absorbed Dose (mg/kg-day)

DA_{event} = Absorbed dose per event (mg/cm^2-event)

SA = Exposed Skin Surface Area (cm^2/day)

EV = Event frequency (events/day)

EF = Exposure Frequency (days/year)

ED = Exposure Duration (year)

BW = Body Weight (kg)

AT = Averaging Time (days)

CS = Soil or Sediment Concentration (mg/kg soil or sediment)

CF = Unit Conversion Factor (kg soil or sediment /10^6 mg soil or sediment)

AF = Soil or Sediment to Skin Adherence Factor (mg soil or sediment /cm^2)

ABS_d = Dermal Absorption Fraction (constituent-specific) (unitless)

5.5.2 Estimating Potential Exposure to COPCs via Inhalation

Exposure to COPC in air (fugitive dust and volatiles) is assumed to occur for many of the potential receptors. The equation used to estimate exposure to COPC in air via inhalation is as follows:

<u>Daily Intake (Lifetime and Chronic) Following Inhalation of COPC (mg/kg-day):</u>

$$\text{Daily Intake} = \frac{CA \times IR \times ET \times EF \times ED}{BW \times AT}$$

where:

CA = Air Concentration (mg/m^3)

IR = Inhalation Rate (m^3/hr)

ET = Exposure Time (hours/day)

EF = Exposure Frequency (days/year)

ED = Exposure Duration (year)

BW = Body Weight (kg)

AT = Averaging Time (days)

5.5.3 Estimating Potential Exposure to COPCs from Groundwater or Surface Water

The future on-site worker, hypothetical future on-site resident, and off-site resident are assumed to contact COPCs in groundwater via ingestion. Several receptors are assumed to contact COPCs in surface water while wading or swimming. The equation used to estimate a receptor's potential exposure via incidental ingestion of groundwater or surface water is:

<u>Daily Intake (Lifetime and Chronic) Following Ingestion of Groundwater or Surface Water (mg/kg-day):</u>

$$\text{Daily Intake} = \frac{CW \times IR \times EF \times ED \times ET}{BW \times AT}$$

where:

CW = Water Concentration (mg/L)

IR = Water Ingestion Rate (L/hr)

EF = Exposure Frequency (days/year)

ED = Exposure Duration (year)

ET = Exposure Time (hour)

BW = Body Weight (kg)

AT = Averaging Time (days)

Calculation of the dose from dermal exposure to surface water follows USEPA guidance (2004a) which differentiates between organics and inorganics, as presented below. The following equations are used to estimate the dermally absorbed dose (DAD) following dermal contact with surface water and groundwater:

$$DAD = \frac{DA_{event} \times EV \times EF \times ED \times SA}{BW \times AT}$$

where:

DAD = Dermally Absorbed Dose (mg/kg-day)

DA_{event} = Absorbed Dose per Event (mg/cm^2-event)

SA = Surface Area (cm^2)

EV = Event Frequency (events/day)

EF = Exposure Frequency (days/year)

ED = Exposure Duration (years)

BW = Body Weight (kg)

AT = Averaging Time (years)

The calculation of the dose absorbed per unit area per event (DA_{event}) is as follows for inorganics or highly ionized organics:

$$DA_{event} = CW \times PC \times ET \times CF$$

where:

DA_{event} = Absorbed Dose per Event (mg/cm^2-event)

CW = Concentration in Water (mg/L)

PC = Permeability Constant (cm/hr)

ET = Exposure Time (hr/event)

CF = Conversion factor (L/1000 cm^3)

The calculation of DAevent is as follows for organics:

If ET < t*, then: $$DA_{event} = 2FA \times PC \times CW \times CF\sqrt{\frac{6T \times ET}{\pi}}$$

If ET > t*, then $$DA_{event} = FA \times PC \times CW \times CF \times \left[\frac{ET}{1+B} + 2T\left(\frac{1+3B+3B^2}{(1+B)^2}\right)\right]$$

where:

DAevent = Absorbed Dose per Event (mg/cm^2-event)

FA = Fraction Absorbed water (dimensionless)

PC = Permeability Constant (cm/hour)

CW = Concentration in Water (mg/L)

T = Lag Time per event (hr/event)

ET = Exposure Time (hr/event)

t* = Time to Steady State (hr) = 2.4T

B = Dimensionless ratio of the PC of a chemical through the stratum corneum relative to its permeability constant across the viable epidermis

CF = Conversion Factor (L/1000 cm^3)

<u>Parameters for Water Dermal Dose Calculation (Groundwater and Surface Water)</u>

The estimation of exposure doses resulting from incidental dermal contact with groundwater or surface water requires the use of a dermal permeability constant (PC) in units of centimeters per hour (cm/hr). This method assumes that the behavior of constituents dissolved in water is described by Fick's Law. In Fick's Law, the steady-state flux of the solute across the skin ($mg/cm^2/hr$) equals the permeability constant (pc, cm/hr) multiplied by the concentration difference of the solute across the membrane (mg/cm^3). This approach is discussed by USEPA (USEPA, 1989; 2004a).

The PC values were derived from USEPA (2004a) Exhibit B-3. In addition to PCs, several other parameters are necessary to calculate dermal dose from exposure to organic compounds in water. These parameters, also obtained from USEPA (2004a), Exhibit B-3, include the ratio of the permeability coefficient of a chemical through the stratum corneum relative to its permeability coefficient across the viable epidermis (B, dimensionless), lag time (τ, hours/event), and time to steady state (t*, hours). Table 5-12 presents the parameters for dermal dose calculation. Parameters not available from USEPA (2004a) were calculated in Table 5-13.

5.5.4 Estimating Potential Exposure From Fish Ingestion

Recreational anglers are assumed to be exposed to bioaccumulatable COPCs through ingestion of fish obtained from Great Miami River. The equation used to estimate a receptor's potential daily intake via fish ingestion is:

Daily Intake (Lifetime and Chronic) Following Fish Ingestion (mg/kg-day):

$$\text{Daily Intake} = \frac{CF \times IR \times EF \times ED}{AT \times BW}$$

where:

CF = Concentration in Fish (mg/kg)

IR = Fish Ingestion Rate (kg/day)

EF = Exposure Frequency (days/year)

ED = Exposure Duration (years)

AT = Averaging Time (days)

BW = Body Weight (kg)

5.6 Calculation of Exposure Point Concentrations

Exposure points are the locations where potential receptors may contact COPCs at or from the Site. The concentrations of COPCs in the environmental medium that receptors may contact, referred to as exposure point concentrations (EPCs), must be estimated in order to determine the magnitude of potential exposure.

EPCs were derived for the HHRA using measurement data where available (e.g., surface soil, groundwater). For potential exposure pathways where measurement data are not available, EPCs were modeled from measured EPCs (e.g., indoor air, fugitive dust, fish tissue).

The estimation of EPCs in media evaluated for the HHRA is discussed below.

5.6.1 Measured EPCs

Measured data are available for surface soil, subsurface soil, groundwater, surface water, and sediment. For soil, sediment, and surface water, the exposure point concentration is defined as the lower of the maximum or 95% UCL on the arithmetic mean concentrations (USEPA, 2002a). EPCs were derived for each exposure area identified for soil, sediment, and surface water (see Section 5.3). For groundwater, the maximum detected concentration in each well was selected as the EPC for that well.

Where no new data are available, EPCs were generated following USEPA Guidance (USEPA, 2002a) and using USEPA ProUCL Version 3.0. For COPCs with fewer than four samples, or with low frequency of detection (less than 25%), the maximum detected concentration was selected as the EPC. For all other COPCs, the lower of the calculated 95% UCL and the maximum detect was selected as the EPC. Sample concentrations were entered into the program after non-detects have been handled as described in Section 3.2, and duplicate results have been averaged.

For those areas with new data available (AOC 13 soil, Southern Parcel soil, Riparian Area hydric soil, and Great Miami River sediment), EPCs were generated following USEPA guidance (USEPA, 2002a; USEPA, 2007b) and USEPA's ProUCL Version 4.00.02 software (USEPA, 2007a,b). The ProUCL recommended UCL (95%, 97.5%, 99%) was used. Based on information presented in the ProUCL guidance (USEPA, 2007b) regarding minimum sample size and frequency of detection, UCLs were calculated where at least 10 samples and at least 6 detects are available. Where too few samples or detects are available, the maximum detected concentration is used. ProUCL version 4.00.02 recommends 10-15 or more distinct results for the most accurate and reliable UCL calculation. When fewer than 10 detects were present in the dataset, the calculations were reviewed individually to determine appropriate UCLs. Where these standards were not met, the maximum detected concentration was used as the EPC. Sample concentrations were entered into the program using full detection limits and after duplicate results were averaged, as described in Section 3.2 for areas with new data.

Appendix E presents the UCL calculation output tables from ProUCL Version 3.0 (areas with no new data) or Version 4.00.02 (areas with new data).

Measured EPCs are presented in Tables 5-14 to 5-19, as discussed below:

- Table 5-14 presents EPCs for surface soil. Surface soil EPCs are used to evaluate the ingestion and dermal contact with surface soil exposure pathway for the trespasser, the hypothetical future on-site resident, and the future on-site worker. Additionally, these EPCs are used to estimate ambient concentrations of particulates for the trespasser, the hypothetical future on-site resident, and the future on-site worker.

- Table 5-15 presents EPCs for combined surface and subsurface soil. These EPCs are used to evaluate the ingestion and dermal contact with soil pathway for the construction worker as well as the excavation air pathway for the construction worker. These EPCs are also used to estimate ambient air concentrations of volatile COPCs for trespasser, the hypothetical future on-site resident, and the future on-site worker.

- Table 5-16 presents the on-site groundwater EPCs, used to evaluate the hypothetical future on-site resident groundwater pathway (drinking water, bathing, vapor intrusion) and the future on-site worker drinking water pathway.

- Table 5-17 presents the off-site groundwater EPCs. Based on the available hydrogeologic data for the Site, shallow Site groundwater discharges to the Great Miami River. However, as previously noted, the Hamilton North Wellfield zone of influence under pumping conditions extends into the Site (USGS, 2005). Therefore, it was conservatively assumed that Site groundwater from the intermediate and deep groundwater may reach the Hamilton North Wellfield (although it should be noted that available hydrogeologic data suggest that intermediate groundwater also discharges to the river and does not migrate beneath the river off-site). The twelve intermediate and deep on-site groundwater wells were used to estimate potential off-site groundwater EPCs (there are two monitoring events for all but MW-17M and MW-27M, which was installed in July 2008). Using this data set, which is conservatively assumed to represent groundwater EPCs at the Hamilton North Wellfield, a total of 14 COPCs were identified (see Table B-3b in Appendix B). EPCs were calculated for COPCs with four or more detected results using ProUCL Version 4.00.02; maximum detects were used for the six COPCs with fewer than six detects (BEHP and five PAH compounds). The off-site groundwater EPCs are highly conservative in that no dilution and attenuation of COPC concentrations is assumed to occur between the Site and Hamilton North Wellfield, and connectivity between intermediate groundwater and off-site groundwater is assumed to exist. As noted above, available hydrogeologic data suggest limited to no connectivity between intermediate and off-site groundwater. The off-site groundwater EPCs are used in the evaluation of the drinking water and bathing pathways for the off-site resident.

- Table 5-18 presents EPCs for sediment and hydric soil in the Riparian Area, which are used in the evaluation of the trespasser and the recreational angler ingestion and dermal contact with sediment and hydric soil pathways.

- Table 5-19 presents EPCs for surface water, which are used in the evaluation of the trespasser and the recreational angler dermal contact with surface water pathway.

5.6.2 Modeled EPCs

Modeled EPCs were required for estimation of COPC concentrations in the following media:

- Fugitive dusts from undisturbed surface soil soils as well as from subsurface soil during construction activities (discussed in Section 5.6.2.1);

- Volatilization of COPCs in surface/subsurface soil to ambient air (Section 5.6.2.2);

- Volatilization of COPCs in groundwater to indoor air (Section 5.6.2.3);

- Bioconcentration of COPCs in surface water to fish tissue and bioaccumulation of COPCs in sediment to fish tissue (Section 5.6.2.4).

- Volatilization of COPCs in groundwater while shower/bathing (Section 5.6.2.5).

5.6.2.1 Fugitive Dust from Soil

The calculation of concentrations of non-volatile COPCs bound to soil in fugitive dust involves multiplying the soil exposure point concentrations by the concentration of dust in air as follows:

Ambient Air (non-excavation scenarios):

COPC concentration in ambient air (mg/m^3) = Surface Soil EPC (mg/kg soil) x Dust concentration (kg soil/m^3)

The dust concentration in air used in the evaluation of ambient outdoor air pathways in this risk evaluation is the inverse of the particulate emission factor (PEF) derived in accordance with U.S. EPA guidance (U.S. EPA, 1996a), using the following equation:

$$\mathrm{PEF}(m^3/kg) = Q/C * \frac{3600\ s/hr}{0.036 * (1-V) * (U_m/U_t)^3 * F(x)}$$

Where,

Q/C	=	Inverse of mean concentration at center of source (g/m^2-s per kg/m^3)
V	=	Fraction of vegetative cover (unitless)
U_m	=	Mean annual windspeed (m/s)
U_t	=	Equivalent threshold value of windspeed at 7 m (m/s)
F(x)	=	Function dependent on U_m/U_t (unitless)

Table 5-20 shows the site-specific parameters used to calculate PEFs. Because the PEF is dependent on the size of the area, two separate PEFs were calculated, based on the size of the exposure areas with COPCs in surface soil. A PEF based on a 10 acre source area was calculated for AOC 2 and a PEF based on a 30 acre source area was calculated for the remaining areas. The PEFs were used to calculate ambient air concentrations to evaluate inhalation exposure to non-volatile COPCs by trespassers, on-site workers, and future residents.

<u>Excavation Air (i.e., during construction activities):</u>

COPC concentration in excavation air (mg/m^3) = Combined soil EPC (mg/kg soil) x Dust concentration (mg soil/m^3) x Unit correction factor (1 kg/10^6 mg)

The dust concentration in air used in the evaluation of excavation air pathways in this risk evaluation is 60 ug/m^3. This value is the recommended concentration of respirable particulates with a mean diameter of 10 microns or less (PM_{10}) for excavation activities (MADEP, 1995). This value was used to evaluate inhalation exposure to non-volatile COPCs by construction workers. Combined soil EPCs were used to derive the excavation air concentrations, as the construction worker is assumed to be exposed to the entire soil column.

5.6.2.2 Volatilization of COPCs from Soil to Ambient Air

The calculation of concentrations of COPCs in outdoor air resulting from volatilization from subsurface soil involves dividing the soil concentration by a constituent-specific volatilization factor (VF), as follows:

COPC concentration in ambient air (mg/m^3) = Combined Soil EPC (mg/kg soil) ÷ Volatilization Factor (m^3 air/kg soil)

The USEPA Soil Screening Guidance (U.S. EPA, 1996a) was followed in calculating site- and constituent-specific volatilization factors, using the following equations:

$$VF(m^3/kg) = (Q/C)\frac{(3.14 D_a T)^{1/2}}{(2 P_b D_a)} 10^{-4}(m^2/cm^2)$$

And:

$$D_a = \frac{[(O_a^{10/3} D_l H' + O_w^{10/3} D_w)/n^2]}{P_b K_d + O_w + O_a H'}$$

Where:

Q/C	=	Inverse of mean concentration at the center of a 0.5 acre square source (g/m^2-s per kg/m^3)
O_a	=	Air filled soil porosity (Lair/Lsoil)
O_w	=	Water filled soil porosity (Lwater/Lsoil)
D_l	=	Diffusivity in air (cm^2/s)
D_w	=	Diffusivity in water (cm^2/s)
D_a	=	Apparent diffusivity (cm^2/s)
n	=	Total soil porosity (Lpore/Lsoil)
P_b	=	Dry soil bulk density (g/cm^3)
K_d	=	Soil-water partition coefficient (cm^3/g) = K_{oc} * F_{oc}
K_{oc}	=	Soil-organic carbon partition coefficient (cm^3/g)
F_{oc}	=	Fraction organic carbon content of soil (g/g)
H'	=	Henry's law constant (dimensionless)
T	=	Exposure Interval (seconds)

Default soil parameters and constituent-specific parameters from USEPA (1996a) were used in the calculation of a volatilization factor for volatiles in soil. The soil parameters used in calculating the volatilization factors are presented in Table 5-21. The default exposure interval presented in USEPA (1996a) is 950,000,000 seconds, which is 30 years. Therefore, VFs were derived for each receptor using the receptor's exposure duration as the exposure interval. Because the resident is evaluated for a 30 year exposure duration for the carcinogenic evaluation (as an adult and a child) and for a 6 year exposure duration for the noncarcinogenic evaluation (as a child), two VFs are calculated for the resident. The exposure interval is the only difference in the receptor VFs. The constituent-specific parameters used in the calculation of the volatilization factors are presented in Table 5-22. The volatilization factors derived for each constituent are presented in Table 5-23. Because the selection of the Q/C value is dependent on the size of the source area, two sets of VFs were calculated. A VF based on a 10 acre source area was calculated for AOC 2 and a VF based on a 30 acre source area was calculated for the remaining areas. The VFs were used to calculate ambient air concentrations to evaluate inhalation exposure to volatile COPCs by trespassers, on-site workers, construction workers, and future residents.

Combined surface and subsurface soil EPCs were used to derive air concentrations for volatilization to outdoor air.

EPCs for the ambient air pathway are presented in Tables 5-24 to 5-28, as follows:

- Table 5-24 – Trespasser. Ambient air EPCs for non-volatiles based on PEF and surface soil EPCs. Ambient air EPCs for volatiles based on VF (trespasser) and combined soil EPC.
- Table 5-25 – Adult/Child Resident. Ambient air EPCs for non-volatiles based on PEF and surface soil EPCs. Ambient air EPCs for volatiles based on VF (adult/child) and combined soil EPC, for use in the carcinogenic evaluation.
- Table 5-26 – Child Resident. Ambient air EPCs for non-volatiles based on PEF and surface soil EPCs. Ambient air EPCs for volatiles based on VF (child) and combined soil EPC, for use in the noncarcinogenic evaluation.
- Table 5-27 – Construction Worker. Excavation air EPCs for non-volatiles based on PEF and combined soil EPCs. Excavation air EPCs for volatiles based on VF (construction worker) and combined soil EPC.
- Table 5-28 – On-Site Worker. Ambient air EPCs for non-volatiles based on PEF and surface soil EPCs. Ambient air EPCs for volatiles based on VF (on-site worker) and combined soil EPC.

5.6.2.3 Volatilization of COPCs from Groundwater to Indoor Air

For the hypothetical future on-site resident indoor air pathway, indoor air EPCs were estimated from groundwater EPCs for volatile COPCs using the USEPA version of the Johnson and Ettinger model (JEM) (USEPA, 2004f).

JEM considers both diffusion of constituents migrating from the subsurface and convection, which is driven by the pressure difference between the subsurface and the building. Equations and parameters required for the implementation of this model are provided in *User's Guide For Evaluating Subsurface Vapor Intrusion Into Buildings* (USEPA, 2004f). Additional guidance on the evaluation of this pathway was obtained from *Draft Guidance for Evaluating the Indoor Air Pathway From Groundwater and Soils* (USEPA, 2002e).

Groundwater COPCs for the vapor intrusion pathway were selected in Appendix B as discussed in Section 3.3.2.

The spreadsheet "GW-ADV-Feb04.XLS", available from the USEPA for implementation of the JEM was used in this HHRA. The advanced version of the JEM was used to allow for up to three different soil strata between the ground surface and the water table. The models were run for a building with basement construction using

USEPA's default depth below grade to bottom of enclosed space floor of 200 cm. Site-specific information on the depth to water table and multiple soil strata for each well with COPCs for the vapor intrusion pathway are provided in Appendix F. Default values recommended by USEPA were used for the remaining inputs to the JEM.

Note that for some wells, the site-specific information was adjusted to meet JEM requirements. The JEM requires that (1) the soil stratum closest to the ground surface be at least as deep as the bottom of the building foundation (200 cm for a basement), (2) only soil strata information above the water table be input in the model, and (3) up to three different soil strata between the ground surface and water table be input into the model. Table F-1 in Appendix F provides the site-specific information as well as the adjustments made for input to the JEM along with the rationale for the adjustment.

For the majority of the wells, these adjustments were simple and would have no effect on the results. For all wells, conservative assumptions were made which may lead to the same or higher estimated indoor air EPC. For example, where the top soil stratum did not extend to the depth of the bottom of the building (requirement (1) above), one of the following two assumptions was made:

- If the top soil stratum was more permeable than the one below it, it was assumed that the top layer of soil extended to the bottom of the basement. This is a conservative assumption because the adjustment increases the thickness of the top soil stratum (which was a more permeable soil type) and decreases the thickness of the soil stratum below it (which was a less permeable soil type).

- In cases where the top soil stratum was the less permeable than the one below it, it was assumed that the top soil stratum was not present and that the more permeable soil stratum was present from the ground surface to the depth at which it is present. This scenario only occurred for two wells (MW-29S and MW-31S). For both of these wells, a sensitivity analysis shows that the same indoor air EPC would be estimated if the less permeable top soil stratum was assumed to extend from the surface to the bottom of the basement.

Well logs supporting the soil type selection for each well are presented in Appendix A of the RI report.

Appendix F presents the groundwater-to-indoor air models. The estimated indoor air concentrations are presented in Table 5-29.

5.6.2.4 Prediction of Fish Tissue EPCs

The prediction of fish tissue concentrations of bioaccumulatable COPCs in surface water involves multiplying surface water EPCs by chemical-specific bioconcentration factors (BCFs). The COPCs in the Great Miami River (including the location where AOC 19 formerly passed beneath the Great Miami River) surface water are iron, mercury, and vanadium. Iron and vanadium are not expected to bioconcentrate from water to fish tissue (USEPA, 1999b). A BCF is available for mercury (methyl mercury) from USEPA (1999b). Table 5-30 presents the fish tissue EPCs for the Great Miami River based on surface water. Due to the lack of dissolved data, the total mercury surface water concentration was used to estimate the fish tissue EPC. This is conservative, as the BCF applies to the dissolved fraction.

Fish tissue concentrations of bioaccumulatable COPCs in sediment were derived using a biota-sediment accumulation factor (BSAF), after adjusting for fish tissue lipid content and total organic carbon in sediment. COPCs in sediment include metals, PAHs, and PCBs. Metals and PAHs are not expected to bioaccumulate from sediment to fish tissue. A default BSAF of 2 is available for PCBs from USEPA (2005b). Fish tissue lipid content was estimated at 0.027, based on lipid content data for sport fish caught in the Great Miami River in the vicinity of the Site. Fish tissue monitoring data were collected by Ohio EPA in 1993, 1998, and 2002 from the Great Miami River at river miles 37 to 39, which falls within the reach adjacent to the Site. The average lipid content is based on 4 composite samples of common carp, 4 composite samples of channel catfish, 3 composite samples of smallmouth bass, and 1 composite sample of golden redhorse.

Predicted fish tissue concentrations were derived for each sediment sample as follows:

$$\text{Fish Tissue Concentration (mg/kg wet weight)} = BSAF \times (Cs/f_{OC}) \times f_L$$

Where:
BSAF = biota/sediment accumulation factor (unitless)
Cs = concentration in sediment (mg/kg dry weight)
f_{OC} = decimal fraction sediment organic carbon, dry weight
f_L = decimal fraction organism lipid, wet weight

UCLs were then calculated for the resulting fish tissue concentrations as described in Section 5.6.1.

5.6.2.5 Volatilization of COPCs from Groundwater While Showering/Bathing

During showering or bathing, it is possible that VOCs present in groundwater will volatilize into the air of a bathroom. To estimate the potential VOC concentrations in shower/bathroom air, a model developed by Paul Sanders (Sanders, 2002) of the New Jersey Department of Environmental Protection (NJDEP) was used. The documentation for the model is presented in Appendix J. The model predicts maximum possible VOC concentrations that could occur in a shower stall based on VOC concentration in water using a simple equilibrium equation:

$$C_{air} = C_{water} \times \frac{HxV_{water}}{HxV_{air} + V_{water}} \qquad V_{water} = F_r \times I \times U$$

Where

C_{air} = Shower stall air concentration (mg/m^3)

C_{water} = Shower water concentration (mg/L)

H = Dimensionless Henry's Law Constant corrected for shower water concentration (40 C)

V_{water} = Volume of water (m^3)

V_{air} = Shower/bath stall volume

F_r = Water flow rate in shower/bath (L/min)

I = Length of shower (minutes)

U = Unit conversion factor (1000 m^3/L)

Groundwater EPCs for off-site groundwater (Table 5-17) are used as the water concentration in the model. [Note that intermediate and deep groundwater wells were conservatively used to estimate potential off-site groundwater concentrations.] Default values listed in the model were used for the shower stall volume (1.5 m^3) and the water flow rate into the shower (m^3). The length of the shower was assumed to be 34.8 minutes under the RME scenario for the adult and15 minutes for the CTE adult (USEPA, 1997a, USEPA, 2004e). The model was also applied to estimate concentrations of VOCs that might occur during a bathing scenario for the child. Air concentrations resulting from drawing a bath are expected to be lower than from showering because water is flowing into the bath for a shorter duration. Therefore, the duration was set to 5 minutes rather than the full bathing time to account for the length of time it takes the bath to fill. The calculations are included in Appendix J. Table 5-17 presents the potential shower and bath air concentrations for the four VOCs detected in intermediate and deep on-site groundwater.

6.0 Risk Characterization

The potential risk to human health associated with potential exposure to COPC at the Site is evaluated in this step of the risk assessment process. Risk characterization is the process in which the dose-response information (Section 4.0) is integrated with quantitative estimates of human exposure derived in the Exposure Assessment (Section 5.0). The result is a quantitative estimate of the likelihood that humans will experience any adverse health effects given the exposure assumptions made. Two general types of health risk are characterized for each potential exposure pathway considered: potential carcinogenic risk and potential noncarcinogenic risk. Carcinogenic risk is evaluated by averaging exposure over a normal human lifetime, which, based on USEPA guidance (1989), is assumed to be 70 years. Noncarcinogenic risk is evaluated by averaging exposure over the total exposure period.

Characterization of the potential impact of potential carcinogenic and noncarcinogenic constituents is approached in very different ways. The difference in approaches arises from the conservative assumption that substances with possible carcinogenic action proceed by a no-threshold mechanism, whereas other toxic actions may have a threshold, a dose below which few individuals would be expected to respond. Thus, under the no-threshold assumption, it is necessary to calculate a risk, but for constituents with a threshold, it is possible to simply characterize an exposure as above or below the threshold. In risk assessment, that threshold is termed a reference dose (RfD). Reference doses as well as cancer slope factors were discussed in Section 4.0. The approach to carcinogenic risk characterization is presented in Section 6.1, and the approach to noncarcinogenic risk characterization is presented in Section 6.2. The risk characterization results are presented in Section 6.3. A summary of the risk characterization results, including COPCs identified as Constituents of Concern (COCs), is presented in Section 6.4. The risk calculation spreadsheets are presented in Appendix D.

6.1 Carcinogenic Risk Characterization

The purpose of carcinogenic risk characterization is to estimate the upper-bound likelihood, over and above the background cancer rate, that a receptor will develop cancer in his or her lifetime as a result of exposure to a constituent in environmental media at the Site. This likelihood is a function of the dose of a constituent (described in the Exposure Assessment, Section 5.0) and the Cancer Slope Factor (CSF) (described in the Dose-Response Assessment, Section 4.0) for that constituent. The Excess Lifetime Cancer Risk (ELCR) is the likelihood over and above the background cancer rate that an individual will contract cancer in his or her lifetime. The American Cancer Society (ACS) estimates that the lifetime probability of contracting cancer in the U.S. is 1 in 2 for men and 1 in 3 for women (ACS, 2004). The risk value is expressed as a probability (e.g., 10^{-6}, or one in one million). The relationship between the ELCR and the estimated LADD of a constituent may be expressed as:

$$ELCR = 1 - e^{-(CSF \times LADD)}$$

When the product of the CSF and the LADD is much greater than 1, the ELCR approaches 1 (i.e., 100 percent probability). When the product is less than 0.01 (one chance in 100), the equation can be closely approximated by:

$$ELCR = LADD\ (mg/kg\text{-}day) \times CSF\ (mg/kg\text{-}day)^{-1}$$

The product of the CSF and the LADD is unitless, and provides an upper-bound estimate of the potential carcinogenic risk associated with a receptor's exposure to that constituent via that pathway.

The potential carcinogenic risk for each exposure pathway is calculated for each receptor. In current regulatory risk assessment, it is assumed that cancer risks are additive or cumulative. Pathway and area-specific risks are summed to estimate the total Site potential cancer risk for each receptor. A summary of the total Site cancer risks for each receptor group is presented in this section and compared to the USEPA's target risk range of 10^{-4} to 10^{-6} (one in ten thousand to one in one million). While remedial action might not be warranted where potential risks exceed 10^{-6} but are below 10^{-4}, for this HHRA, any COPC exceeding the 10^{-6} risk level for a particular receptor is designated a COC. The target risk levels used for the identification of COCs are based on USEPA direction for the site. It should be noted that USEPA provides the following guidance (USEPA, 1991a):

> "Where the cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4}, and the non-carcinogenic hazard quotient is less than 1, action generally is not warranted unless there are adverse environmental impacts." and,

> "The upper boundary of the risk range is not a discrete line at 1 x 10^{-4}, although EPA generally uses 1 x 10^{-4} in making risk management decisions. A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions."

Therefore, while COCs have been identified using a 10^{-6} risk level, further risk management determinations will be made and remedial action may not be warranted for all COCs.

6.2 Noncarcinogenic Risk Characterization

The potential for exposure to a constituent to result in adverse noncarcinogenic health effects is estimated for each receptor by comparing the CADD for each COPC with the RfD for that COPC. The resulting ratio, which is unitless, is known as the Hazard Quotient (HQ) for that constituent. The HQ is calculated using the following equation:

$$HQ = \frac{CADD\ (mg/kg\text{-}day)}{RfD\ (mg/kg\text{-}day)}$$

The target HQ is defined as a HQ of less than or equal to one (USEPA, 1989). When the HQ is less than or equal to 1, the RfD has not been exceeded, and no adverse noncarcinogenic effects are expected. If the HQ is greater than 1, there may be a potential for adverse noncarcinogenic health effects to occur; however, the magnitude of the HQ cannot be directly equated to a probability or effect level.

The total Hazard Index (HI) is calculated for each exposure pathway by summing the HQs for each individual constituent. The total Site HI is calculated for each potential receptor by summing the HIs for each pathway associated with the receptor. Where the total Site HI is greater than 1 for any receptor, a more detailed evaluation of potential noncarcinogenic effects based on specific health or target endpoints (e.g., liver effects, neurotoxicity) is performed (USEPA, 1989), as described below. The target HI is 1 on a per target endpoint basis. Each COPC that causes an exceedance of the HI of 1 for a particular receptor and for a particular target endpoint is designated a COC. RME results are considered in the identification of COCs.

Toxic Endpoint Evaluation

When the HQ is less than one, the reference dose (RfD) has not been exceeded, and no adverse noncarcinogenic health effects are expected. A total receptor-specific Hazard Index (HI) was calculated for each exposure pathway by summing the HQ for each individual constituent for that receptor. This approach accounts for the possibility that the toxicity of all COPCs are additive and should be regarded only as a screening assessment because additive toxicity may not be correct. Where the HI is greater than one, further evaluation to identify COPCs that may be additive (or otherwise interactive) in their toxicity was conducted. Toxicologically, only the HQs of constituents having similar toxic endpoints can be added together to provide an HI for a given effect.

Where the total HI is above one, toxic endpoint tables are presented in Appendix G. The toxic endpoints based on chronic oral and inhalation exposures to COPCs are presented in Table G-1, and the toxic endpoints based on subchronic exposures are presented in Table G-2. The toxic endpoints shown in Tables G-1 and G-2 were identified using the target organ information in the dose-response tables (Tables 4-1 to 4-4) presented in Section 4.0. A single COPC can have more than one toxic endpoint. For example, the HQ for ethylbenzene is appropriately additive with other COPCs that have "liver effects" identified as a toxic endpoint. However, because the toxic endpoint for ethylbenzene is identified as liver and kidney toxicity, the HQ for ethylbenzene is also added with the HQ for other COPCs exhibiting kidney effects. The results of the toxic endpoint evaluation are presented with the risk characterization results for each receptor, where applicable.

6.3 Risk Characterization Results

The results of the risk characterization are summarized for each receptor below. Summary tables indicating the total potential risk and HI for each area are presented Tables 6-1 to 6-6. Total potential risks and hazards by receptor, COPC, area, and pathway are presented in Tables 6-7 to 6-24. The results of the lead modeling conducted in Appendix C for the hypothetical future on-site resident child and the future on-site worker are also presented below.

6.3.1 Current and Future Trespasser

The current and future trespasser was evaluated for potential exposure to COPCs in on-site surface soil via ingestion, dermal contact, and inhalation of particulates in outdoor air. The trespasser was also evaluated for potential exposure to surface and subsurface soil COPCs via inhalation of volatiles in outdoor air. The trespasser was also evaluated for potential exposure to COPCs in sediment and surface water in the Great Miami River and the intermittent stream (AOC 7) via ingestion and dermal contact with sediment and dermal contact with surface water. In addition, the trespasser was evaluated for potential exposure to hydric soil in the Riparian Area (AOC 22) via incidental ingestion and dermal contact.

As shown in Table 6-7 and summarized in Table 6-1, the total potential carcinogenic risk for the trespasser is within the target cancer risk range of 1×10^{-6} to 1×10^{-4} in all areas. However, the total potential carcinogenic risk exceeds 1×10^{-6} in several areas for the trespasser. Potential COCs are identified as follows:

- AOC 1
    - o arsenic and PCBs in surface soil (0-2 feet bgs)
    - o benzene in soil (0-10 feet bgs)
- AOC 2
    - o arsenic and benzo(a)pyrene in surface soil (0-2 feet bgs)
- AOC 18 and 21
    - o arsenic, benzo(a)pyrene, and dibenz(a,h)anthracene in surface soil (0-2 feet bgs)
- AOC 19
    - o arsenic in surface soil (0-2 feet bgs)
- Block A
    - o benzo(a)pyrene in surface soil (0-2 feet bgs)
- Southern Parcel
    - o arsenic and benzo(a)pyrene in surface soil (0-2 feet bgs)

- AOC 13
    - o arsenic, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene in surface soil (0-2 feet bgs)
    - o benzene in soil (0-10 feet bgs)
- Intermittent Stream (AOC 7)
    - o benzo(a)pyrene and dibenzo(a,h)anthracene in sediment
- Great Miami River
    - o benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene in sediment
- Riparian Area (AOC 22)
    - o benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene in hydric soil

As shown in Table 6-8 and summarized in Table 6-1, the total HI exceeds 1 for two areas (AOC 1 and AOC 13). Therefore, toxic endpoint analyses were conducted for these two areas in Appendix G. The results for AOC 1 (Table G-3) indicate that the HI is below one for all endpoints, with the exception of immune effects, finger and toenail effects, and eye effects. Ingestion and dermal contact with PCBs drives this exceedance. PCBs in surface soil (0-2 feet bgs) is therefore identified as a COC in AOC 1. No adverse health effects based on the remaining noncarcinogenic COPCs with individual HQs less than one in AOC 13 are expected. The results for AOC 13 (Table G-4) indicate that the HI is below one for all endpoints with the exception of nasal effects. Inhalation of naphthalene in outdoor air drives this exceedance. Naphthalene in soil (0 -10 feet bgs) is therefore identified as a potential COC in AOC 13. No adverse health effects based on the remaining noncarcinogenic COPCs with individual HQs less than one in AOC 13 are expected.

6.3.2 Recreational Angler

The current and future recreational angler was evaluated for potential exposure to COPCs in sediment and surface water in the Great Miami River via ingestion and dermal contact for sediment and dermal contact for surface water, and via ingestion and dermal contact with hydric soil in the Riparian Area (AOC 22). The recreational angler was assumed to ingest fish caught in the river.

As shown in Table 6-9 and summarized in Table 6-2, the total potential carcinogenic risk for the angler is within the target cancer risk range of 1×10^{-6} to 1×10^{-4} in the Riparian Area (but is greater than 1×10^{-5}), and above the target risk range in both reaches of the Great Miami River where the recreational angler is assumed to fish. COCs are identified for each area as follows:

- Great Miami River
    - o benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene in sediment
    - o PCBs in the sediment to fish tissue pathway
- Great Miami River (AOC 19)
    - o PCBs in the sediment to fish tissue pathway

- Riparian Area (AOC 22)
    - benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene in hydric soil

The majority of the potential risk identified in both reaches of the Great Miami River is related to the sediment to fish tissue pathway. Therefore, potential risks were calculated for an upgradient reach, using the same methods used for the reaches adjacent to the site. As shown in Table 6-9, the potential risk due to fish ingestion in the upgradient area of the Great Miami River exceeds $1x10^{-3}$ and is greater than the potential risks identified adjacent to the site. The potential contribution of background to the PCB fish risks is discussed further in the Uncertainty Analysis.

Potentially carcinogenic PAH in Great Miami River sediment adjacent to the Site also pose potential direct contact risks in excess of 1×10^{-6}, and for two PAH, in excess of 1×10^{-5}. This risk is driven largely by one sediment sample (SD-6), and to a lesser extent nearby sample SD-31. Potentially carcinogenic PAH concentrations in other sediment samples along the reach of the Great Miami River adjacent to the Site are 10 to 100-fold lower than concentrations in these two samples. The potential for these PAH to be present in river sediment as a result of non-Site sources is discussed further in the Uncertainty Analysis (Section 7).

As shown in Table 6-10 and summarized in Table 6-2, the total HI exceeds 1 in the reach of the Great Miami River where the former COG pipeline passed beneath the river and in the Great Miami River. In both cases, the exceedance is driven by ingestion of mercury and PCBs in fish tissue. Because the HQ is above one for mercury and PCBs, no toxic endpoint evaluation was conducted and mercury and PCBs are identified as potential COCs in river surface water (mercury) and sediment (PCBs). As with the potential carcinogenic risk assessment noted above for the upgradient reach, the potential HI in the upgradient reach is greater than the potential HI in the reaches adjacent to the site.

Lead was identified as a COPC in Great Miami River sediment. The adult lead model was used to estimate blood lead concentrations for a fetus of an adult angler, as described in Appendix C. The target blood lead level is 10 ug/dL. The results (Table 6-10a) indicate that blood lead levels are below the target level of 10 ug/dL, and no adverse effects are expected.

6.3.3 Hypothetical Future On-Site Resident

The hypothetical future on-site resident (adult and child) was evaluated for potential exposure to COPCs in surface soil via incidental ingestion and dermal contact, and inhalation of particulates in outdoor air. The hypothetical future on-site resident was also evaluated for potential exposure to surface and subsurface soil COPCs via inhalation of volatiles in outdoor air. Additionally, the hypothetical future on-site resident was evaluated for ingestion of on-site groundwater used as drinking water and dermal contact with tap water while bathing. Potential exposure to volatile groundwater COPCs via inhalation (vapor intrusion to indoor air) was also evaluated. While household use of groundwater was not evaluated quantitatively, it is assumed that there is some exposure, particularly to volatile constituents, during household use of water, such as washing dishes, doing laundry, cleaning, etc. If groundwater with high levels of VOCs is used, there is potential for inhalation risks during household use of the groundwater, however, this risk is expected to be less than risks from consumption of the groundwater as drinking water. As previously noted, future use of the Site is anticipated to continue to be non-residential, ensured via an institutional control. Thus, it is highly unlikely that on-site shallow, intermediate or deep groundwater will be used for potable or domestic purposes in the foreseeable future.

As shown in Table 6-11 and summarized in Table 6-3, the total potential carcinogenic risk for the hypothetical future on-site resident is greater than the target cancer risk range of $1x10^{-6}$ to $1x10^{-4}$ in all areas. As shown in Table 6-12 and summarized in Table 6-3, the total HI exceeds 1 in all areas. Both soil and groundwater contributed significantly to the risk exceedances. Primary risk drivers in soil include PCBs, PAHs, benzene, xylenes, arsenic, iron, manganese. Primary risk drivers in groundwater include PCBs, PAHs, benzene, arsenic, iron, manganese, and vanadium.

Lead was identified as a COPC in surface soil for AOC 1, AOC 19, and the Southern Parcel, and in both surface soil and groundwater (well MW-21S) in AOC 13. The IEUBK model was used to evaluate potential exposure to lead in soil for a residential child for these areas and groundwater in AOC 13, as described in Appendix C. The USEPA regulatory target is at least 95% of young children in a population potentially exposed to lead having blood lead levels below 10 ug/dl. The results are compared to this target and summarized below:

- AOC 1 – Model results indicate that 16% of young children potentially exposed to lead under the condition summarized above are predicted to exhibit blood lead concentrations greater than the target blood lead level of 10 ug/dl and 84% have blood lead levels less than 10 ug/dl. Therefore, under the conditions described above, lead presents a potentially unacceptable risk for residential children at AOC 1.
- AOC 19 - Model results indicate that 1% of young children potentially exposed to lead under the condition summarized above are predicted to exhibit blood lead concentrations greater than the target blood lead level of 10 ug/dl and 99% have blood lead levels less than 10 ug/dl. Therefore, under the conditions described above, lead does not present a potentially unacceptable risk for residential children at AOC 19.
- Southern Parcel - Model results indicate that 0.6% of young children potentially exposed to lead under the condition summarized above are predicted to exhibit blood lead concentrations greater than the target blood lead level of 10 ug/dl and 99.4% have blood lead levels less than 10 ug/dl. Therefore, under the conditions described above, lead does not present a potentially unacceptable risk for residential children at the Southern Parcel.
- AOC 13 – Model results indicate that 6% of young children potentially exposed to lead under the condition summarized above are predicted to exhibit blood lead concentrations greater than the target blood lead level of 10 ug/dl and 94% have blood lead levels less than 10 ug/dl. Therefore, under the conditions described above lead slightly exceeds (by 1%) the regulatory target and potentially presents unacceptable risk for residential children in AOC 13.

Potentially unacceptable risks were identified under the residential scenario for all exposure areas for a number of COPCs. Based on the results of the hypothetical future on-site resident scenario risk assessment, it is concluded that institutional controls should be placed on the property such that future residential development and use of groundwater as drinking water are prohibited. Thus, further risk evaluation of the hypothetical future on-site resident, such as target organ and CTE analyses, is not necessary and is not performed.

The one exception is AOC 19, which is the off-site portion of the former COG pipeline. For AOC 19, arsenic in surface soil drives the total carcinogenic risk and the majority of the noncarcinogenic hazard index. A review of the arsenic soil data for AOC 19 reveals that one of 13 surface soil samples contains elevated arsenic (101 mg/kg arsenic at sample location AOC19SB8AA located north of Route 73). Arsenic concentrations at the remaining 12 surface soil locations along the former COG pipeline range from 5 to 20 mg/kg. Based on a review of tax assessor maps, the sample point AOC19SB8AA appears to be located on land owned by AK Steel. Arsenic in surface soil is also evaluated further with regard to consistency with background in Section 7.1.2. As discussed in Section 7.1.2, arsenic in surface soil in all AOCs is found to be consistent with site-specific local background.

6.3.4 Current and Future Off-Site Resident

The current and future off-site downgradient resident (adult and child) was evaluated for potential exposure to COPCs in groundwater at the Hamilton North Wellfield via ingestion of groundwater as drinking water and dermal contact with and inhalation of volatile COPCs in tap water while bathing. As previously noted, it was conservatively assumed that Site groundwater from the intermediate and deep wells may reach the Hamilton North Wellfield without any dilution or attenuation.

As shown in Table 6-13 and summarized in Table 6-4, the total potential carcinogenic risk for the off-site resident is greater than the target cancer risk range of $1x10^{-6}$ to $1x10^{-4}$. The exceedance is driven by ingestion of and dermal contact with several COPCs while bathing, which are therefore identified as potential COCs:

- arsenic
- benzene
- benzo(a)pyrene
- bis(2-ethylhexyl)phthalate (BEHP)

It should be noted that the model used to estimate dermal contact with PAHs may overestimate the dermal dose PAHs (due to the high molecular weight, high log K_{ow}, and permeability coefficients outside the model's effective prediction range for PAHs) (USEPA, 2004a). Additionally, only dissolved concentrations of PAHs are able to penetrate the skin, and it is possible that the two samples with elevated benzo(a)pyrene (2006 sample from MW-8M and 2008 sample from MW-27M) contained suspended particulates. These issues are considered further in the uncertainty section (Section 7.0).

As shown in Table 6-14 and summarized in Table 6-4, the total HI exceeds 1 for the drinking water ingestion pathway. Several COPCs have HIs above one and are identified as COCs, including:

- 1-methylnaphthalene
- 2-methylnaphthalene
- cyanide
- naphthalene

A toxic endpoint analysis was conducted to evaluate the remaining COPCs, which is presented in Appendix G. The results (Table G-5) indicate that the HI is below one for all endpoints, and that no adverse health effects are expected from the other COPCs with HI below one. At the request of USEPA, the potential for exposure to volatiles in groundwater during showering/bathing was evaluated for the off-site resident. As shown in Table 6-4, the potential carcinogenic risk posed by this potential exposure pathway is negligible, and the potential noncarcinogenic hazard index is below one.

6.3.5 Future Construction Worker

A future construction/utility worker was evaluated for potential exposure to constituents in surface and subsurface soil (ingestion, dermal contact, inhalation of particulates and volatiles). Construction/utility work is assumed to occur to a maximum depth of 10 feet bgs.

As shown in Table 6-15 and summarized in Table 6-5, the total potential carcinogenic risk for the construction worker is within the target cancer risk range of $1x10^{-6}$ to $1x10^{-4}$ in all areas. However, the potential risk exceeds $1x10^{-6}$ in all areas. Therefore, the following COCs are identified in soil (0-10 feet bgs):

- AOC 1
    - benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, PCBs, benzene

- AOC 18 and 21
  - benzo(a)pyrene
- Block A
  - benzo(a)pyrene
- Southern Parcel
  - benzo(a)pyrene
- AOC 13
  - benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, benzene

As shown in Table 6-16 and summarized in Table 6-5, the total HI exceeds 1 for four areas (AOC 1, Block A, Southern Parcel, and AOC 13). Therefore, toxic endpoint analyses were conducted for these areas in Appendix G. The results of the toxic endpoint evaluation are discussed below:

- The results for AOC 1 (Table G-6) indicate that the HI is below one for all endpoints with the exception of nasal effects, immune effects, finger and toenail effects, and eye effects. Inhalation of naphthalene in outdoor air drives the nasal effects exceedance, and ingestion and dermal contact with PCBs (0-2 feet bgs) drive the remaining exceedances. Naphthalene in combined soil (0 -10 feet bgs) and PCBs in surface soil (0-2 feet bgs) are therefore identified as potential COCs in AOC 1. No adverse health effects from the remaining noncarcinogenic COPCs with individual HQs less than one in AOC 1 are expected. It should be noted that the PCBs risk in AOC 1 is driven by one surface soil sample (AOC1CA9 with 121 mg/kg PCBs). Total PCB concentrations in the remaining 16 surface soil samples are less than 1.6 mg/kg. In addition, the naphthalene risk in AOC 1 is driven by one subsurface soil sample (AOC1CA12 with 1100 mg/kg naphthalene). Naphthalene concentrations in the remaining 33 surface and subsurface soil samples from AOC 1 are less than 2.2 mg/kg, with the exception of one sample containing 10 mg/kg naphthalene.

- The results for Block A (Table G-7) indicate that the HI is equal to or below one for all endpoints, with the exception of nervous system effects. This exceedance is driven by inhalation of manganese in outdoor air. Manganese in soil (0-10 feet bgs) is therefore identified as a COC. No adverse health effects from the remaining noncarcinogenic COPCs with individual HQs less than one in Block A are expected.

- The results for the Southern Parcel (Table G-8) indicate that the HI is equal to or below one for all endpoints, and that no adverse health effects are expected.

- The results for AOC 13 (Table G-9) indicate that the HI is below one for all endpoints with the exception of nasal effects. Inhalation of naphthalene in outdoor air drives the nasal effects exceedance. Naphthalene in soil (0 -10 feet bgs) is therefore identified as a potential COC in AOC 13. No adverse health effects for the remaining noncarcinogenic COPCs with individual HQs less than one in AOC 13 are expected.

Lead was identified as a COPC in soil (0-10 feet bgs) in four areas. The adult lead model was used to estimate blood lead concentrations for a fetus of an adult worker, as described in Appendix C. The target blood lead level is 10 ug/dL. The results of the lead modeling are presented below:

- The results for AOC 1 (Table 6-17) indicate that blood lead levels may be elevated above the target of 10 ug/dL. Therefore, lead is identified as a potential COC in soil for this area. The lead risk in AOC 1 is driven by four samples in surface and subsurface soil (AOC1CA9CAA, AOC1CA9CBA, AOC1CA10CBA, and MW-17SBA with lead concentrations ranging from 1660 mg/kg to 3840 mg/kg. The remaining 30 samples have lead concentrations less than 400 mg/kg.

- The results for AOC 19 (Table 6-18) indicate that blood lead levels are below the target level of 10 ug/dL, and no adverse effects are expected.
- The results for the Southern Parcel (Table 6-19) indicate that blood lead levels are below the target level of 10 ug/dL, and no adverse effects are expected.
- The results for AOC 13 (Table 6-19a) indicate that blood lead levels are below the target level of 10 ug/dL, and no adverse effects are expected.

6.3.6 Future On-Site Worker

The future on-site worker was evaluated for potential exposure to COPCs in surface soil on-site via ingestion, dermal contact, and inhalation of particulates in outdoor air. Inhalation of volatile surface and subsurface soil COPCs in outdoor air was also evaluated. A second scenario, not discussed in the work plan, in which it is assumed that subsurface soils are brought to the surface is also evaluated. In the second scenario, all soils are treated as surface soils. Both scenarios are considered future scenarios as there are no workers currently on-site. However, because the first scenario evaluates soil conditions as they currently exist, the scenario is referred to as the current soil scenario, while the second scenario is referred to as the future soil scenario. The future on-site worker was also evaluated for potential exposure to COPCs via ingestion of groundwater used as drinking water. The drinking water risk calculated for each well was summed with the soil-related risks for the corresponding AOC within which the well is located. For example, the drinking water risk for MW-1S was summed with the soil risks for AOC 1. Potential risks and hazards for the soil scenarios and the drinking water pathway are discussed separately below.

<u>**Current Soil Scenario**</u>

As shown in Table 6-20a and summarized in Table 6-6a, the total potential carcinogenic risk for the future on-site worker is within the target cancer risk range of 1×10^{-6} to 1×10^{-4} in all areas except for AOC 13. However, potential risks exceed 1×10^{-6} in all areas. The following are identified as potential COCs in soil under the current soil scenario:

- AOC 1
  - arsenic, benzo(a)pyrene, and PCBs in surface soil (0-2 feet bgs)
  - benzene in soil (0-10 feet bgs)
- AOC 2
  - arsenic, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and PCBs in surface soil (0-2 feet bgs)
- AOC 18 and 21
  - arsenic, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and PCBs in surface soil (0-2 feet bgs)
- AOC 19
  - arsenic, benzo(a)pyrene, and dibenz(a,h)anthracene in surface soil (0-2 feet bgs)

- Block A
    - o arsenic, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, in surface soil (0-2 feet bgs)
    - o benzene in soil (0-10 feet bgs)
- Southern Parcel
    - o arsenic, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene,in surface soil (0-2 feet bgs)
- AOC 13
    - o arsenic, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and PCBs in surface soil (0-2 feet bgs)
    - o benzene in soil (0-10 feet bgs)

As shown in Table 6-21a and summarized in Table 6-6a, the total HI exceeds 1 for multiple areas. Therefore, toxic endpoint analyses were conducted for these areas in Appendix G (Tables G-10 through G-30). Based on the toxic endpoint analysis, the majority of the HIs are below one on a toxic endpoint basis. Areas/pathways with HI greater than one under the current soil scenario on a toxic endpoint basis are listed below along with the identified potential COCs:

- Soil - AOC 1: Inhalation of naphthalene in outdoor air volatilized from soil (0 -10 feet bgs) and ingestion/dermal contact with PCBs in surface soil (Tables G-10 and G-11).
- Soil - AOC 13: Inhalation of naphthalene in outdoor air volatilized from soil (0 -10 feet bgs) (Tables G-23 to G-30).

The naphthalene hazard index in AOC 1 (hazard index of approximately 2) is driven by one subsurface soil sample (AOC1CA12 with 1100 mg/kg naphthalene). Naphthalene concentrations in the remaining 33 surface and subsurface soil samples from AOC 1 are less than 2.2 mg/kg, with the exception of one sample containing 10 mg/kg naphthalene. The naphthalene hazard index in AOC 13 is driven by multiple subsurface soil samples with elevated concentrations, including the sample with the highest naphthalene concentration detected in AOC 13 soil (MW20SBA at approximately 8 ft bgs with 31,000 mg/kg naphthalene and AOC13SB2BA at approximately 4 ft bgs with 720 mg/kg naphthalene). The EPC for naphthalene in AOC 13 combined soil is 2,860 mg/kg which exceeds the soil saturation limit for naphthalene of 375 mg/kg. If the soil saturation limit is used in lieu of the statistically derived EPC (as allowed by the volatilization model), the resulting inhalation HI for naphthalene in AOC 13 soil would be approximately eight-fold lower (HI of 2.2). Further, the models used by USEPA to estimate volatilization from soil to ambient air are known to be conservative (e.g., assume infinite source), as discussed in USEPA guidance (2002b). It is very likely that use of more refined volatilization modeling methods, such as EMSOFT, would result in acceptable ambient air concentrations of naphthalene and the resulting hazard index for naphthalene in AOC 1 and AOC 13 would drop to below 1.

Lead was identified as a COPC in surface soil (0-2 feet bgs) in four areas. The adult lead model was used to estimate blood lead concentrations for a fetus of an adult worker, as described in Appendix C. The target blood lead concentration is 10 ug/dL. The results of the lead modeling are presented below:

- The results for AOC 1 (Table 6-22) indicate that blood lead levels are below the target level of 10 ug/dL, and no adverse effects are expected.

- The results for AOC 19 (Table 6-23) indicate that blood lead levels are below the target level of 10 ug/dL, and no adverse effects are expected.
- The results for the Southern Parcel (Table 6-24) indicate that blood lead levels are below the target level of 10 ug/dL, and no adverse effects are expected.
- The results for AOC 13 (Table 6-24a) indicate that blood lead levels are below the target level of 10 ug/dL, and no adverse effects are expected.

Future Soil Scenario

As shown in Table 6-20b and summarized in Table 6-6b, the total potential carcinogenic risk for the future on-site worker is within the target cancer risk range of $1x10^{-6}$ to $1x10^{-4}$ in AOC 2, AOC 18 and 21, and AOC 19, and is greater than $1x10^{-4}$ in AOC 1, the Southern Parcel, and AOC 13. Potential risks exceed $1x10^{-6}$ in all areas. The following are identified as potential COCs in soil under the future soil scenario:

- AOC 1
  - arsenic, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and PCBs in soil (0-10 feet bgs)
  - benzene in soil (0-10 feet bgs)
- AOC 2
  - arsenic, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and PCBs in soil (0-10 feet bgs)
- AOC 18 and 21
  - arsenic, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and PCBs in soil (0-10 feet bgs)
- AOC 19
  - arsenic, benzo(a)pyrene, and dibenz(a,h)anthracene in soil (0-10 feet bgs)
- Block A
  - arsenic, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene in soil (0-10 feet bgs)
  - benzene in soil (0-10 feet bgs)
- Southern Parcel
  - arsenic, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene in soil (0-10 feet bgs)
- AOC 13
  - arsenic, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and PCBs in soil (0-10 feet bgs)
  - benzene in soil (0-10 feet bgs)

As shown in Table 6-21b and summarized in Table 6-6b, the total HI exceeds 1 for multiple areas. Therefore, toxic endpoint analyses were conducted for these areas in Appendix G (Tables G-10 through G-30). Based on the toxic endpoint analysis, the majority of the HIs are below one on a toxic endpoint basis. Areas/pathways with HI greater than one under the current soil scenario on a toxic endpoint basis are listed below along with the identified potential COCs:

- Soil - AOC 1: Inhalation of naphthalene in outdoor air volatilized from soil (0 -10 feet bgs) and ingestion/dermal contact with PCBs in surface soil (Tables G-10 and G-11).

- Soil - AOC 13: Inhalation of naphthalene in outdoor air volatilized from soil (0 -10 feet bgs) (Tables G-23 to G-30).

The sample information regarding naphthalene in AOC 1 and AOC 13 soil presented above for the on-site worker current soil scenario also applies to the naphthalene hazard index results for the future soil scenario.

Lead was identified as a COPC in soil (0-10 feet bgs) in four areas. The adult lead model was used to estimate blood lead concentrations for a fetus of an adult worker, as described in Appendix C. The target blood lead concentration is 10 ug/dL. The results of the lead modeling are presented below:

- The results for AOC 1 (Table 6-22) indicate that blood lead levels are below the target level of 10 ug/dL, and no adverse effects are expected.

- The results for AOC 19 (Table 6-23) indicate that blood lead levels are below the target level of 10 ug/dL, and no adverse effects are expected.

- The results for the Southern Parcel (Table 6-24) indicate that blood lead levels are below the target level of 10 ug/dL, and no adverse effects are expected.

- The results for AOC 13 (Table 6-24a) indicate that blood lead levels are below the target level of 10 ug/dL, and no adverse effects are expected.

Drinking Water

The potential risks and hazards for drinking water under both soil scenarios are the same; therefore, Tables 6-6a and 6-6b, Tables 6-20a and 6-20b, and Tables 6-21a and 6-21b present the same information for groundwater. The "a" series tables are referred to here for simplicity. As shown in Table 6-20a and summarized in Table 6-6a, the total potential carcinogenic risk for the future on-site worker drinking water scenario is within or below the target cancer risk range of $1x10^{-6}$ to $1x10^{-4}$ in all wells except for those in AOC 13. However, potential risks exceed $1x10^{-6}$ in all wells. The following are identified as potential COCs in groundwater:

Area	Well	Potential COC
Northern Parcel: AOC 1	MW-17S	Arsenic
Southern Parcel (Except AOC 13)	MW-01S	Arsenic Benzo(a)pyrene
	MW-02S	Arsenic
	MW-03D	Arsenic
	MW-03S	Arsenic
	MW-04M	Arsenic
	MW-04S	Arsenic
	MW-07M	Arsenic
	MW-19S	Arsenic
	MW-23S	Benzo(a)pyrene

Area	Well	Potential COC
Southern Parcel: AOC 13	MW-08M	Benzo(a)pyrene
	MW-08S	Benzene Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(k)fluoranthene Carbazole Chrysene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene
	MW-09M	Benzene
	MW-09S	Arsenic Benzene Benzo(a)anthracene Benzo(a)pyrene
	MW-20M	Arsenic
	MW-20S	Benzene Benzo(a)pyrene
	MW-21M	Arsenic
	MW-21S	Arsenic Benzene Vinyl chloride
	MW-27M	Benzene Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Dibenz(a,h)anthracene Indeno(1,2,3-cd)pyrene
	MW-27S	Benzene Benzo(a)pyrene
	MW-28S	Benzene
	MW-29S	Arsenic
	MW-31S	Tetrachloroethene

As shown in Table 6-21 and summarized in Table 6-6, the total HI exceeds 1 for multiple areas. Therefore, toxic endpoint analyses were conducted for these areas in Appendix G (Tables G-10 through G-30). Based on the toxic endpoint analysis, the majority of the HIs are below one on a toxic endpoint basis. Wells with HI greater than one on a toxic endpoint basis are listed below along with the identified potential COCs in groundwater:

- AOC 13 (MW-8S): Ingestion of benzene, 2,4-dimethylphenol, 1-methylnaphthalene, 2-methylnaphthalene, dibenzofuran, and naphthalene in drinking water (Table G-24).

- AOC 13 (MW-9S): Ingestion of benzene, cyanide, naphthalene, toluene in drinking water (Table G-26).

- AOC 13 (MW-21M): Ingestion of cyanide in drinking water (Table G-30).

- AOC 13 (MW-21S): Ingestion of arsenic and cyanide in drinking water (Table G-30).

- AOC 13 (MW-27M): Ingestion of cyanide in drinking water (Table G-30).
- AOC 13 (MW-27S): Ingestion of 1-methylnaphthlene, 2-methylnaphthalene, benzene, dibenzofuran, and naphthalene in drinking water (Table G-30).
- AOC 13 (MW-28S): Ingestion of benzene and cyanide in drinking water (Table G-30).

Lead was identified as a COPC in AOC 13 groundwater (MW-21S). Because the adult lead model does not include a drinking water exposure pathway, an additional model (Bowers, 1994) was employed. As indicated in Appendix C, the Bowers model indicates that blood lead levels from combined exposure to soil via ingestion and inhalation and to groundwater are below the target level of 10 ug/dL, and no adverse effects are expected.

6.4 Summary of Risk Characterization Results

Based on the risk characterization results, a number of receptors/pathways/areas pose potential risks within or in excess of the USEPA target risk range of 10^{-6} to 10^{-4}. The potential COCs are summarized below. At the request of USEPA, potential COCs for potential carcinogens were selected based on the low end of the USEPA target cancer risk range of 10^{-6} to 10^{-4}. The majority of the potential risks do not exceed the upper end of the range, as described in Section 6.3. Remedial actions may not be warranted for all the COCs identified. However, the information is provided such that risk management decisions can be made.

Table 6-25 summarizes the potential COCs for soil for the trespassing teenager, the future construction worker, and the future on-site worker (current and future soil scenarios). Potential COCs were identified in all soil areas evaluated, (AOC 1, AOC 2, AOC 18 and 21, AOC 19, Block A, the Southern Parcel, and AOC 13) and include:

- Metals
  - Arsenic
  - Lead
  - Manganese
- PAHs
  - Benzo(a)anthracene
  - Benzo(a)pyrene
  - Benzo(b)fluoranthene
  - Benzo(k)fluoranthene
  - Dibenz(a,h)anthracene
  - Indeno(1,2,3-cd)pyrene
  - Naphthalene
- Volatiles
  - Benzene
- PCBs

Table 6-25 presents in detail which of the above COCs apply to each area and receptor.

Table 6-26 summarizes the potential COCs for sediment, hydric soil, and surface water for the trespassing teenager and the recreational angler. Potential COCs were identified in the intermittent stream (AOC 7), the Great Miami River adjacent to the site, the Great Miami River near the location of the Former COG Pipeline (AOC 19) and the Riparian Area (AOC 22). COCs in sediment and hydric soils include:

- PAHs
    - Benzo(a)anthracene
    - Benzo(a)pyrene
    - Benzo(b)fluoranthene
    - Benzo(k)fluoranthene
    - Dibenz(a,h)anthracene
    - Indeno(1,2,3-cd)pyrene
- PCBs. Note that the potential risks from PCBs are related to fish tissue concentrations modeled from sediment. As described previously, there are many uncertainties associated with this modeling which likely have overestimated fish tissue concentrations. Measured fish tissue concentrations (OEPA, 1993, 1998, 2002) ranged from non-detect to 1 mg/kg whereas modeled concentrations from GMR sediment resulted in tissue estimates of 0.73 mg/kg at AOC19, 2.5 mg/kg adjacent to the site and 10.1 mg/kg upstream. Furthermore, potential risks associated with the upgradient reach of the Great Miami River exceed those adjacent to the Site.

Mercury was identified as a potential COC in surface water in both reaches of the Great Miami River. As with PCBs, the potential mercury hazard is associated with modeled fish tissue concentrations. The potential hazard is likely overestimated due to the uncertainties inherent in the modeling.

As previously noted, risks in excess of 10^{-4} and/or a hazard index of 1 were identified under the hypothetical future on-site residential scenario for all exposure areas for a number of COPCs. Based on these results, no further evaluation of the future on-site residential scenario is recommended, and institutional controls should be placed on the property such that residential development and use of groundwater are prohibited.

Table 6-27 summarizes the potential COCs for groundwater for the hypothetical future on-site worker drinking water scenario. As noted above, a restriction against groundwater use on site is recommended. Therefore, while potential COCs are identified for completeness, remedial actions may not be warranted because an institutional control will prevent the exposure that could result in potentially unacceptable risks. Potential COCs were identified in a number of wells, including the following:

- Northern Parcel – MW-17S (arsenic only, at a concentration below its federal drinking water standard or maximum contaminant level (MCL))
- Southern Parcel – MW-1S, MW-2S, MW-3D, MW-3S, MW-4M, MW-4S, MW-7M, MW-19S, MW-23S (arsenic in all but one well and benzo(a)pyrene in two wells, all at concentrations below their MCLs)
- AOC 13 – MW-8M, MW-8S, MW-9M, MW-9S, MW-20M, MW-20S, MW-21S, MW-21S, MW-27M, MW-27S, MW-28S, MW-29S, MW-31S

The following potential COCs were identified; see Table 6-27 for a detailed listing of which COCs apply to each well:

- Inorganics
  - Arsenic
  - Cyanide
- PAHs
  - 1-Methylnaphthalene
  - 2-Methylnaphthalene
  - Benzo(a)anthracene
  - Benzo(a)pyrene
  - Benzo(b)fluoranthene
  - Benzo(k)fluoranthene
  - Chrysene
  - Dibenz(a,h)anthracene
  - Indeno(1,2,3-cd)pyrene
  - Naphthalene
- Semivolatiles
  - 2,4-Dimethylphenol
  - Carbazole
  - Dibenzofuran
- Volatiles
  - Benzene
  - Tetrachloroethene
  - Toluene
  - Vinyl chloride

Table 6-28 summarizes the potential COCs for groundwater for the future off-site resident drinking water scenario. A total of eight COCs are identified:

- arsenic
- benzene
- benzo(a)pyrene

- bis(2-ethylhexyl)phthalate (BEHP)
- 1-methylnaphthalene
- 2-methylnapthalene
- cyanide
- naphthalene

As previously noted, this evaluation assumes that Site groundwater from the intermediate and deep wells migrates off-site and reaches the Hamilton North Wellfield without any dilution or attenuation. This is clearly an overly conservative assumption. In addition, as previously noted, available hydrogeologic data suggest that intermediate groundwater discharges to the river and does not migrate beneath the river off-site. This is significant because concentrations of COPCs are generally higher in intermediate groundwater than deep groundwater. Last, as discussed in the Uncertainty Analysis (Section 7.4.3), the on-site wells that are the source of the potentially unacceptable risk to the off-site resident receptor are located in AOC 13.

6.4.1 Summary

In summary, a number of COCs are identified when the lower end of the target risk range (10^{-6}) is used as the trigger. However, the majority of the potential carcinogenic risks estimated in this baseline HHRA do not exceed the upper end of the USEPA's target risk range of 10^{-6} to 10^{-4}. As stated in USEPA guidance (USEPA, 1991a), remedial actions are typically not warranted "where the cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4}, and the non-carcinogenic hazard quotient is less than 1." Thus, for a number of COCs and areas identified in this site-specific baseline risk assessment, remedial action is not expected to be necessary. However, the information is provided such that informed risk management decisions can be made. In the subsequent Uncertainty Analysis (Section 7.0), further evaluation of the risk characterization results is performed to identify those COCs that truly warrant remedial action and/or further evaluation. The evaluations performed in Section 7.0 entail refinements allowed by USEPA guidance, including consideration of consistency with background and analysis of central tendency exposure (CTE) scenarios.

7.0 Uncertainty Analysis

Within any of the four steps of the risk assessment process, assumptions must be made due to a lack of absolute scientific knowledge. Some of the assumptions are supported by considerable scientific evidence, while others have less support. Every assumption introduces some degree of uncertainty into the risk assessment process. Regulatory risk assessment methodology requires that conservative assumptions be made throughout the risk assessment to ensure that public health is protected. Therefore, when all of the assumptions are combined, it is much more likely that risks are overestimated rather than underestimated.

The assumptions that introduce the greatest amount of uncertainty in this risk assessment are discussed in this section. They are discussed in qualitative terms, because for most of the assumptions there is not enough information to assign a numerical value to the uncertainty that can be factored into the calculation of risk.

7.1 Data Evaluation

The constituents detected in various Site media were screened against risk-based screening levels. Constituents exceeding these concentrations were selected as COPCs for quantitative evaluation in the risk assessment. A subset of constituents detected at a site is generally selected for quantitative analysis for several reasons. Some constituents detected at a site may be naturally occurring and not related to site use; however, a comparison to background was not included in the COPC selection process. Other constituents may be present at concentrations that can be assumed with reasonable assurance not to pose a risk to human health. A review of the results of risk assessments demonstrate that in most cases risks are attributable only to one or a few constituents, and that many of the constituents quantitatively evaluated do not contribute significantly to total risk estimates (USEPA, 1993a). The screening process is conducted to identify the COPCs that may contribute the greatest to potential risk. ~~The screening process used here is conservative.~~ Although the excluded constituents may pose a finite level of risk, that risk would contribute negligibly to the total site risk. Therefore, not evaluating the excluded constituents does not measurably affect the numerical estimates of hazard or risk, and does not affect remedial decision-making at the Site.

An evaluation of detection limits is provided in Section 7.1.1. A comparison to background was conducted for potential risk drivers, as discussed in Section 7.1.2.

7.1.1 Detection Limit Evaluation

At the request of USEPA (as discussed in the June 27, 2006 project call), constituents that were analyzed for but not detected in Site media were evaluated relative to their risk-based screening levels. It was agreed upon in the project call that the Uncertainty Analysis is the appropriate place for this evaluation to be discussed. The detection limit evaluation included the following:

- For compounds that were not detected, minimum and maximum detection limits (DLs) were compared to human health risk-based screening levels (this analysis was performed on an exposure area basis using the same risk-based screening levels used in the COPC selection process, including dividing PRGs for noncarcinogens by 10);
- The following statistics were identified for each exposure area – number of NDs exceeding screening value: total number of NDs; and
- Non-detect compounds without screening levels were identified.

Tables H-1 through H-5 in Appendix H present the results of the detection limit evaluation for surface soil, subsurface soil, groundwater, sediment, and surface water, respectively. For each medium, the following screens were performed: 1) all constituents analyzed for but not detected within each exposure area; 2) constituents where the maximum DL exceeds the screening level; 3) constituents where the minimum DL exceeds the screening level; and 4) constituents lacking a screening level. Because this evaluation was performed on an exposure area basis, it is more informative to consider the results of the minimum DL screen, as it represents the lowest detection limit achieved within each exposure area. The table presenting the comparison of the minimum detection limit with the screening level is presented in the C series of Tables H-1 through H-5. A column presenting the ratio of the exceedance of the minimum detection limit to the screening level is included (i.e., how much the minimum detection limit exceeds the screening level).

As shown in Tables H-1 through H-5, a number of constituents were not detected in one or more media at the Site. Many of these are organic compounds, some of which are included on the Target Compound List (TCL) for VOCs and SVOCs, but are not expected to be found at the Site. A number of organic compounds identified are members of a family (such as PAHs), and related members with higher toxicity were already included in the HHRA. Therefore, exclusion of these non-detect members of the family is not expected to have a substantive effect on risk results. It should further be noted that for most of the organic compounds in soil, the minimum detection limits achieved are quite low and consistent with the reporting limits (RLs) identified in the Quality Assurance Project Plan (QAPP) (ENSR, 2005).

A review of the minimum detection limit screening tables for surface soil (Table H-1C) and subsurface soil (Table H-2C) shows that the minimum detection limit for all constituents exceeds its screening level by less than a factor of 5 (except for thallium in one AOC). These results show that for all non-detect constituents in soil, the minimum detection limits achieved at the Site approach the conservative risk-based screening levels used (residential soil PRGs). For this reason and the fact that the screening levels for noncarcinogens include a 10-fold factor to account for potential additivity, the exclusion of these constituents as soil COPCs is not expected to have resulted in an underestimate of risk for the AOCs where they were not detected.

Because of the nature of the Site, inorganics are of particular interest. For surface and subsurface soil media, antimony and thallium are the only two inorganics where detection limits exceed screening values. As noted above, the screening levels for noncarcinogens (which includes antimony and thallium) include a ten-fold factor to account for potential additivity. Without the "additivity factor" of ten, antimony and thallium minimum detection limits achieve their screening levels (residential soil PRGs). Further, thallium and antimony were included as COPCs in the HHRA for certain AOCs, and were found to not contribute significantly to total Site risk. Therefore, the exclusion of antimony and thallium as COPCs in the AOCs where they were not detected is not expected to have resulted in underestimates of risk at these AOCs.

Antimony and thallium were also not detected in site-wide groundwater. Antimony's minimum detection limit is 5 times higher than its screening level (tap water PRG), and thallium's minimum detection limit is 14.5 times its screening level (tap water PRG). However, if the minimum detection limit for these two inorganics is compared to the MCL (the basis of the reporting limit specified in the QAPP), antimony achieves its MCL and thallium comes within a factor of 2 of its MCL. Since on-site groundwater is not expected to be used for drinking water in the future, detection limit exceedances of drinking water criteria are expected to be of limited significance.

In sediment, the minimum detection limits for thallium exceed the screening level (residential soil PRG) by about 11 in the three sediment exposure areas. However, residential soil PRGs are very conservative human health screening criteria for sediment. Therefore, exclusion of thallium as a COPC for sediment is not expected to have resulted in underestimates of sediment risk. For the other compounds not detected in sediment, all of which are organics not expected to be Site-related, the ratio of exceedance of the minimum detection limits to the screening levels ranges from 1 to 6. Given the conservative screening criteria used for sediment, these exceedances are not significant.

The minimum detection limits for a number of chemicals in surface water did not achieve their surface water screening levels. However, they generally met or exceeded the reporting limits established in the QAPP for these constituents (ENSR, 2005).

For soil and sediment, only a limited suite of four SVOC constituents lack screening criteria and their minimum detection limits met their reporting limits established in the QAPP. For groundwater, there are no non-detect constituents lacking screening criteria. For surface water, there are a number of constituents lacking screening criteria, however, their minimum detection limits generally met or exceeded the reporting limits established in the QAPP for these constituents (ENSR, 2005).

7.1.2 Use of ½ SQL in Calculating UCLs

The draft HHRA was submitted to USEPA in September 2006, prior to the release of Version 4.0 of ProUCL. Prior to the release of Version 4.0, ½ SQLs were often used as proxy values for non-detect results when calculating 95% UCLs in risk assessments. Version 4.0 of ProUCL released in 2007 provides software which can assign proxy values based on the underlying data distribution (i.e., the Kaplan-Meier Method). Because the UCLs had previously been generated, an evaluation was conducted to determine the potential impact of using ½ detection limits. UCLs were derived for selected cases using ProUCL Version 4 to compare with the previously calculated UCLs from ProUCL Version 3.0.

Table A-1 in Attachment A of Appendix K (Response to Comments) summarizes the results of this comparison for 12 cases including surface soil, surface and subsurface soil combined, surface water, and sediment. The frequency of detection varies among these 12 cases from as low as 35% to as high as 100%, and as few as 5 samples to as many as 70 samples. As shown in Table A-1, the two sets of UCLs are the same or similar for eight of the 12 cases. The Version 4.0 UCL is higher for two cases and the Version 3.0 UCL calculated using ½ SQL for non-detect values is higher for two cases. Of the eight cases with a frequency of detection of 74% or less (i.e., the data sets with a higher percentage of censored data), the predicted UCL using Version 3.0 and simple substitution of ½ SQL is the same or lower than the Version 4.0 UCL in seven of the eight cases.

In summary, simple substitution of ½ SQL appears to generate UCL concentrations that are similar to UCLs calculated using alternate statistical methods that have been incorporated into ProUCL Version 4.0, including for data sets with a higher percentage of censored data.

For areas with additional data collected since the submission of the draft HHRA in 2006, ProUCL Version 4.0 was used to derive UCLs.

7.1.3 Background Evaluation

The results of background soil sampling were used in a background evaluation to determine whether any of the key COPCs in soil may be attributable to natural background, and not be Site-related. Sections 2.10 and 4.28 of the Draft RI/FS Report (ENSR, 2006) discuss the background soil sampling and analysis performed for the Site. In short, eleven surface soil (0-2 feet bgs) samples and one duplicate and nine subsurface soil (3-4 feet bgs) samples were collected from off-site and unimpacted on-site locations and analyzed for TAL metals. The surface samples were also analyzed for dioxins/furans and PAHs. The background soil samples are listed in Table 3-6. In addition, three slag composite samples (BGSLAG-1AA, -2AA, and-3AA) were collected in Block A (the former slag processing area) from a slag pile that appeared to be unimpacted from other operations and consisting entirely of historically processed slag. The background slag samples were analyzed for TAL metals.

The background comparison was conducted in accordance with the USEPA *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (USEPA, 2002d), and as documented in responses to USEPA's comments on the draft HHRA. For the three soil areas with new soil data (AOC 13, Southern Parcel, and AOC 22), as agreed upon with USEPA, the latest version of ProUCL (Version 4.00.02) was used to perform the background evaluation. Appendix I describes the methods and results in detail, including an addendum that summarizes the updated evaluations. Surface soil data for a limited suite of inorganics and potentially carcinogenic PAH were included in this background evaluation. Based on the risk results, inorganics in subsurface soil and slag are generally not risk drivers. However, because of the influence of background levels of arsenic on risk results, a background evaluation was also performed for arsenic in subsurface soil in all areas. Lead was also identified as an inorganic of interest in combined soil at

AOC 1, thus lead was included in the subsurface soil background evaluation. To be consistent with the combined surface and subsurface soil exposure point concentrations used in the HHRA, surface and subsurface background samples were combined for the background evaluation.

Based on the results of the background evaluation, concentrations of several COPCs in on-site surface soil were found to be consistent with background surface soil concentrations. The potential risks presented for these COPCs in Section 6 are therefore likely to be related to background and not the Site. Notable among the chemicals identified as consistent with background surface soil are arsenic and potentially carcinogenic PAH in all AOCs, as well as mercury and iron in several AOCs. These results should be considered in the evaluation of potential risks due to surface soil. The CERCLA program does not require clean up to concentrations below natural or anthropogenic background levels (USEPA, 2002f).

Surface Soil COPCs Consistent with Background

AOC 1	Arsenic
	Mercury
	Carcinogenic PAHs
AOC 2	Arsenic
	Iron
	Mercury
	Carcinogenic PAHs
AOC 13	Arsenic
	Iron
	Lead
	Vanadium
	Carcinogenic PAHs
AOC 18 and 21	Arsenic
	Iron
	Mercury
	Carcinogenic PAHs
AOC 19	Arsenic
	Iron
	Manganese
	Mercury
	Carcinogenic PAHs
AOC 22	Aluminum
	Arsenic
	Iron
	Lead
	Vanadium
	Carcinogenic PAHs
Block A	Arsenic
	Mercury
	Carcinogenic PAHs
Southern Parcel (excluding AOC 13)	Arsenic
	Lead
	Carcinogenic PAHs

Based on the background evaluation for combined surface and subsurface soil, arsenic and lead in all soil exposure areas are consistent with background.

A quantitative background evaluation was not performed for the potentially carcinogenic PAH compounds detected in the AOC 7 intermittent stream "sediment". The AOC 7 intermittent stream is a meandering, dry-bed drainage feature which serves to convey stormwater runoff from an area north of the Great Miami River into the river. The northern portion of the AOC 7 channel runs parallel to and north of the eastern boundary of the closed landfill (AOC 2). The substrate in AOC 7 is primarily sand, gravel, and cobble, with little depositional environments present, and is not characteristic of typical sediment, such as in the River. In fact, because of the intermittent nature of the stream flow in AOC 7, the Screening Level Ecological Risk Assessment (SLERA) performed for AOC 7 compared constituents to both sediment- and soil-based ecological screening values (ENSR, 2008). For comparison purposes, the range of potentially carcinogenic PAH compounds detected in the four AOC 7 substrate samples was compared with the range of potentially carcinogenic PAH compounds detected in background surface soil samples.

- Concentrations of potentially carcinogenic PAH detected in AOC 7 substrate range from ~0.1 mg/kg to a maximum of 17 mg/kg in one sample (benzo(a)anthracene in AOC7SD13). Concentrations in three of the four AOC 7 samples are all less than 1 mg/kg.
- Concentrations of potentially carcinogenic PAH detected in the background surface soil range from ~0.05 mg/kg to a maximum of 8.6 mg/kg, with individual cPAH concentrations in many of the background surface soil samples of 1 to 4 mg/kg.

Based on this qualitative comparison, it is reasonable to conclude that the levels of carcinogenic PAH detected in AOC 7 substrate are consistent with typical background concentrations in surface soil impacted by historical anthropogenic activities, including the nearby railroad.

A quantitative background evaluation was also not performed for the potentially carcinogenic PAH compounds detected in Great Miami River sediment. It is not known if the PAH compounds detected in river sediment are a result of historical site release, background conditions, or disturbance and deposition during a high water event. The presence of low levels of PAHs along the river may represent background conditions of the river system and be the result of sediment redistribution in the river during storm events. PAHs are a ubiquitous contaminant in industrialized river systems such as the Great Miami River. PAHs are detected in all seven upstream sediment samples at concentrations ranging from 0.05 mg/kg to 14.4 mg/kg total PAH. With the exception of one localized area with elevated PAH in the vicinity of SD-6 and SD-31, total PAH concentrations in sediment samples adjacent to the Site range from 0.2 mg/kg to 13.8 mg/kg, which is consistent with upstream concentrations. In summary, PAH concentrations in River sediment are considered to be related to upstream conditions in the Great Miami River and not solely attributable to the Site.

With regard to background conditions in groundwater, three on-site monitoring wells (MW-6S, MW-10S, and MW-14S) installed during the remedial investigation, are considered representative of upgradient groundwater conditions based on groundwater elevation data (ENSR, 2006). The analytical results from these wells should be considered in evaluation of background contributions of inorganics to potential groundwater risks.

7.2 Dose-Response Assessment

The purpose of the dose-response assessment is to identify the types of adverse health effects a constituent may potentially cause and to define the relationship between the dose of a constituent and the likelihood or magnitude of an adverse effect (response). Risk assessment methodologies typically divide potential health effects of concern into two general categories: effects with a threshold (noncarcinogenic) and effects assumed to be without a threshold (potentially carcinogenic). Toxicity assessments for both of these types of effects share many of the same sources of uncertainty. To compensate for these uncertainties, USEPA's RfDs and CSFs are biased to overestimate rather than underestimate human health risks. Several of the more important sources of uncertainty and the resulting biases are discussed below.

7.2.1 Animal-to-Human Extrapolation in Noncarcinogenic Dose-Response Evaluation

For many constituents, animal studies provide the only reliable information on which to base an estimate of adverse human health effects. Extrapolation from animals to humans introduces a great deal of uncertainty into the risk characterization. In most instances, it is not known how differently a human may react to the constituent compared to the animal species used to test the constituent. If a constituent's fate and the mechanisms by which it causes adverse effects are known in both animals and humans, uncertainty is reduced. When the fate and mechanism for the constituent are unknown, uncertainty increases.

The procedures used to extrapolate from animals to humans involve conservative assumptions and incorporate uncertainty factors such that overestimation of effects in humans is more likely than underestimation. When data are available from several species, the lowest dose that elicits effects in the most sensitive species is used for the calculation of the RfD. To this dose are applied uncertainty factors, generally of 1 to 10 each, to account for intraspecies variability, interspecies variability, study duration, and/or extrapolation of a low effect level to a no effect level. Thus, most RfDs used in risk assessment are 100- to 10,000-fold lower than the lowest effect level found in laboratory animals.

Nevertheless, because the fate of a constituent can differ in animals and humans, it is possible that animal experiments will not reveal an adverse effect that would manifest itself in humans. This can result in an underestimation of the effects in humans. The opposite may also be true: effects observed in animals may not be observed in humans, resulting in an overestimation of potential adverse human health effects.

7.2.2 Evaluation of Carcinogenic Dose-Response

Significant uncertainties exist in estimating dose-response relationships for potential carcinogens. These are due to experimental and epidemiologic variability, as well as uncertainty in extrapolating both from animals to humans and from high to low doses. Three major issues affect the validity of toxicity assessments used to estimate potential excess lifetime cancer risks: (1) the selection of a study (i.e., data set, animal species, matrix the constituent is administered in) upon which to base the calculations, (2) the conversion of the animal dose used to an equivalent human dose, and (3) the mathematical model used to extrapolate from experimental observations at high doses to the very low doses potentially encountered at the Site.

Study Selection

Study selection involves the identification of a data set (experimental species and specific study) that provides sufficient, well-documented dose-response information to enable the derivation of a valid CSF. Human data (e.g., from epidemiological studies) are preferable to animal data, although adequate human data sets are relatively uncommon. Therefore, it is often necessary to seek dose-response information from a laboratory species, ideally one that biologically resembles humans (e.g., with respect to metabolism, physiology, and pharmacokinetics), and where the route of administration is similar to the expected mode of human exposure (e.g., inhalation and ingestion). When multiple valid studies are available, the USEPA generally bases CSFs on the one study and site that show the most significant increase in tumor incidence with increasing dose. In some cases this selection is done in spite of significant decreases with increasing dose of tumor incidence in other organs and total tumor incidence. Consequently, the current study selection criteria are likely to lead to overestimation of potential cancer risks in humans.

Interspecies Dose Conversion

The USEPA derivation of human equivalent doses by conversion of doses administered to experimental animals requires the assumption that humans and animals are equally sensitive to the toxic effects of a substance, if the same dose per unit body surface area is absorbed by each species. Although such an assumption may hold for direct-acting genotoxicants, it is not necessarily applicable to many indirect acting carcinogens and likely overestimates potential risk by a factor of 6 to 12 depending on the study species (USEPA, 1992). Further assumptions for dose conversions involve standardized scaling factors to account for differences between humans and experimental animals with respect to life span, body size, breathing rates, and other physiological parameters. In addition, evaluation of risks associated with one route of administration (e.g., inhalation) when tests in animals involve a different route (e.g., ingestion) requires additional assumptions with corresponding additional uncertainties.

High-to-Low Dose Extrapolation

The concentration of constituents to which people are potentially exposed at industrial sites is usually much lower than the levels used in the studies from which dose-response relationships are developed. Estimating potential health effects at such sites, therefore, requires the use of models that allow extrapolation of health effects from high experimental doses in animals to low environmental doses. These models are generally statistical in character and have little or no biological basis. Thus the use of a model for dose extrapolation introduces uncertainty in the dose-response estimate. In addition, these models contain assumptions that may also introduce a large amount of uncertainty. Generally the models have been developed to err on the side of over-estimating rather than under-estimating potential health risks.

The USEPA CSFs are derived using the upper 95% confidence limit of the slope predicted by the linearized multi-stage (LMS) model used to extrapolate low dose risk from high dose experimental data. USEPA recognizes that this method produces very conservative risk estimates, and that other mathematical models exist. USEPA states that the upper-bound estimate generated by the LMS model leads to a plausible upper limit to the risk that is consistent with some of the proposed mechanisms of carcinogenesis. The true risk, however, is unknown and may be as low as zero. The LMS model is very conservative as it assumes strict linearity between the lowest dose that produced an effect and zero dose. However, the body has many mechanisms to detoxify constituents, especially at low doses, and many mechanisms to repair damages if they should occur. Therefore, many scientists believe that most constituents can cause cancer only above a "threshold" dose.

USEPA has developed new carcinogen risk assessment guidelines (USEPA, 2005a) that revise and replace the previous carcinogen risk assessment guidelines. USEPA (2005a) places greater emphasis on critically evaluating available data from which a default option may be invoked if needed in the absence of critical information. The guidance also emphasizes the use of mode of action data. Mode of action is defined as a sequence of key events and processes, starting with interaction of an agent with a cell and resulting in cancer formation. Some modes of action are anticipated to be mutagenic and are assessed with a linear approach. Other modes of action may be modeled with either linear or nonlinear approaches after a rigorous analysis of available data under the guidance provided in the framework for mode of action analysis. As discussed in Section 4.3, USEPA (2005a) uses a weight of evidence narrative rather than the classification system that was used in the previous guidance.

7.2.3 Uncertainty in TCE Toxicity Value

The USEPA published a range of oral and inhalation cancer slope factors for trichloroethene (TCE), which are still draft and provisional (USEPA, 2001). Because of uncertainty in the USEPA's draft provisional CSFs, some regulatory agencies including Ohio EPA (2005) have adopted the CalEPA's CSFs for TCE until USEPA's TCE Risk Assessment is finalized. Therefore, the CalEPA oral and inhalation CSFs for TCE were used in this risk assessment. It should be noted that TCE is a minor COPC in this HHRA. It is a COPC only in soil in one AOC, and contributes negligibly to total Site risk.

7.2.4 Uncertainty in Iron Toxicity Value

Iron is an essential nutrient and there is considerable uncertainty in the oral toxicity value provided by USEPA and used in the HHRA. It is a provisional value with a medium level of confidence assigned by the agency. The reference dose is below (more stringent than) the Recommended Daily Allowances (RDAs) for young children (the receptor group evaluated for noncarcinogenic effects from drinking water exposure) (Institute of Medicine, 2001). In addition, the NOAEL (that the provisional RfD for iron of 0.3 mg/kg-day is based on) represents the upper bound value in the range of mean dietary (including supplemental) iron intakes.

Repeated oral-dose studies in experimental animals found no significant effect from treatment with inorganic iron compounds. Human studies showing minimal effects contained "confounding factors, inadequate endpoint assessment, and too short a duration or too few subjects" according to NCEA.

7.3 Exposure Assessment

Exposure assessment consists of three basic steps: 1) development of exposure scenarios, (2) estimation of exposure point concentrations, and 3) estimation of human dose.

7.3.1 Exposure Scenarios

Exposure scenarios in a risk assessment are selected to be representative of potential exposures to COPCs in media that may be experienced by human receptors based on current and reasonably foreseeable land use. These exposure scenarios are developed for a hypothetical receptor, but one that would represent the reasonable maximal exposure (RME) scenario for the Site. Therefore, exposure levels are assumed for these receptors that are much greater than expected to occur in an actual population. For select receptors and exposure pathways, a second scenario is considered to evaluate the potential risks under an average scenario, the Central Tendency Exposure (CTE). Under this scenario, exposure assumptions are meant to reflect more typical exposures rather than upper-bound.

7.3.2 Estimation of Exposure Point Concentrations

Sample Statistics. Exposure to COPCs at the Site is best estimated by the use of the arithmetic mean concentration of a COPC in each medium. Because of the uncertainty associated with estimating the true average concentration at a site, the USEPA has required the use of the 95% UCL on the arithmetic mean as the EPC (USEPA, 2002a). Therefore, this is a very conservative estimate of the true arithmetic mean. EPCs in this risk assessment for soil, sediment, and surface water represent the lower of the maximum detected concentration or the 95% UCL on the mean (USEPA, 2002a). UCLs were calculated using USEPA's ProUCL Version 3.0 software (USEPA, 2004d) and Version 4.0 software (USEPA, 2007a,b) for areas with new data collected since 2006. Uncertainty can arise if the test results show the data set to be normally distributed when it is actually lognormally distributed, or vice-versa. This source of uncertainty, however, is unlikely to lead to large differences in the calculated dose for a given receptor. EPCs for groundwater represent the maximum detected concentration in each well.

Sample Location. In addition, the data used to calculate the EPCs are assumed to be representative of specific exposure areas and general site conditions. Sample locations in the various exposure areas were identified to be as representative of site conditions as possible.

Air Modeling. Models were used to derive both indoor and outdoor concentrations of volatile constituents, and outdoor concentrations of non-volatile constituents. Although assumptions are made about constituent behavior in each of these models, the assumptions used are conservative in that they tend to result in over-predictions rather than under-predictions of air concentrations.

Fish Tissue Modeling. A BCF was used to estimate the concentration of mercury in fish tissue based on surface water concentrations in the Great Miami River. The levels of mercury measured in the Great Miami River adjacent to and upstream of the Site represent total mercury, and only the dissolved fraction is expected to bioaccumulate into fish. Additionally, the BCF used is based on the assumption that the mercury is present as methyl mercury, when in reality it is likely that only a small fraction of the mercury is present in this form. USGS has measured methyl mercury concentrations in fish tissue samples from the Great Miami River (USGS, 2001). Two smallmouth bass caught on the Great Miami River at Hamilton contained 0.113 mg/kg mercury (wet weight). This concentration is below the predicted fish tissue concentrations, which are 0.34 mg/kg for the reach on Great Miami River adjacent to AOC 19 and 1.54 mg/kg for the reach adjacent to the Site. These data suggest that the use of total mercury surface water concentrations with the methyl mercury BCF of 11,168 L/kg results in an overestimate of the fish tissue burden.

A default biota-sediment accumulation factor (BSAF) was used to estimate the concentration of PCBs in fish tissue based on sediment and total organic carbon concentrations in the Great Miami River. There is considerable uncertainty in the BSAF approach and likely overpredicts tissue concentrations. An average lipid concentration based on actual fish caught in the Great Miami River was used, which is expected to reasonably estimate lipid content of edible fish in the river. Fish tissue concentrations were also predicted for the upstream areas. The highest predicted fish tissue concentration in the upstream area is about 4 times higher than that derived for the portion of the river adjacent to the Site. Therefore, potential PCB concentrations in sediment and fish tissue appear to be related to background conditions in the Great Miami River and not the Site. It should be noted that the Great Miami River from Indian Lake to its confluence with the Ohio River is under a fish consumption advisory for PCBs in several species of sportfish (OEPA, 2008). The overconservatism in the BSAF model is further supported by actual measured PCB concentrations in fish samples collected from the Great Miami River in the vicinity of the site. Based on Ohio EPA fish monitoring data from 1993, 1998, and 2002 for carp, smallmouth bass, catfish and redhorse, total PCBs in fish tissue range from non-detect to approximately 1 mg/kg, well below modeled concentrations using USEPA's default BSAF. Tissue data for fish collected in the river adjacent to the Site are provided in Table 7-1.

Environmental Degradation. Finally, it is assumed that the EPCs calculated in the risk assessment based on current Site conditions remain constant for the assumed exposure duration – for an industrial or residential scenario this is a period of 25 to 30 years. However, it is well known in the scientific community that constituents in the environment are subject to natural attenuation and biodegradation processes. Organic constituents are naturally degraded in the environment by a variety of processes (i.e., photodegradation, microbial activity, hydrolysis, etc.). Environmental half-lives vary for specific constituents based on environmental conditions (i.e., presence of bacteria, pH, exposures to sunlight and oxygen), and there are respected literature sources of such information. However, environmental degradation is not typically accounted for in the calculation of risks for hazardous waste sites. This has likely resulted in an over-estimation of Site risks.

7.3.3 Exposure Assumptions

When estimating potential human doses (i.e., intakes) from potential exposure to various media containing COPCs, several assumptions are made. Uncertainty may exist, for example, in assumptions concerning rates of ingestion, frequency and duration of exposure, and bioavailability of the constituents in the medium. Typically, when limited information is available to establish these assumptions, a conservative (i.e., health-protective) estimate of potential exposure is employed. Default exposure assumptions recommended by the USEPA are intended to be conservative and representative of an individual who consistently and frequently contacts environmental media at a site, a scenario that rarely occurs. Most individuals will contact media at non-site locations, while the risk assessment assumes that all exposure to environmental media will occur at the Site. Moreover, it is often assumed that contact with environmental media occurs in the areas having the highest constituent concentrations for the entire exposure frequency/duration used in the risk assessment, due to both statistical handling of the data and the original sampling plan.

The assumptions regarding exposure frequency and duration are very conservative. For example, while the agency default for working tenure is 25 years, the average occupational tenure for an industrial/commercial worker is 4.2 years. As another example, the agency RME estimate for adult shower duration is approximately 35 minutes (USEPA, 1997a). However, according to Burmaster (1998), less than 0.1% of the population showers for longer than 25 minutes. The use of conservative assumptions is likely to lead to an overestimate of potential risk.

7.4 Risk Characterization

The potential risk of adverse human health effects is characterized based on estimated potential exposures and potential dose-response relationships. Three areas of uncertainty are introduced in this phase of the risk assessment: the evaluation of potential exposure to multiple constituents, the combination of upper-bound exposure estimates with upper-bound toxicity estimates, and the risk to sensitive populations.

7.4.1 Risk from Multiple Constituents

Once potential exposure to and potential risk from each COPC is estimated, the total upper-bound potential risk posed by the Site is determined by combining the estimated potential health risk from each of the COPCs. Presently, potential carcinogenic effects are added unless evidence exists indicating that the COPCs interact synergistically (a combined effect that is greater than a simple addition of potential individual effects) or antagonistically (a combined effect that is less than a simple addition of potential individual effects) with each other. For most combinations of constituents, little if any evidence of interaction is available. Therefore, additivity is assumed.

For noncarcinogenic effects, the HI should only be summed for constituents that have the same or similar toxic endpoints (USEPA, 1989). The toxic endpoint is defined as the most sensitive noncarcinogenic health effect used to derive the RfD or other suitable toxicity value (USEPA, 1989). Again, there is little evidence to suggest whether those COPCs associated with a common toxicity endpoint are additive, synergistic, antagonistic, or independent in terms of mechanism of action. Whether assuming additivity leads to an underestimation or overestimation of risk is unknown.

Combination of Several Upper-Bound Assumptions

Generally, the goal of a risk assessment is to estimate an upper-bound, but reasonable, potential exposure and risk. Most of the assumptions about exposure and toxicity used in this evaluation are representative of statistical upper-bounds or even maxima for each parameter. The result of combining several such upper-bound assumptions is that the final estimate of potential exposure or potential risk is extremely conservative (health-protective).

This is best illustrated by a simple example. Assume that potential risk depends upon three variables (soil consumption rate, COPC concentration in soil and CSF). The mean, upper 95% bound and maximum are available for each variable.

One way to generate a conservative estimate of potential risk is to multiply the upper 95% bounds of the three parameters in this example. Doing so assumes that the 5% of the people who are most sensitive to the potential carcinogenic effects of a COPC will also ingest soil at a rate that exceeds the rate for 95% of the population, and that all the soil these people eat will have a constituent concentration that exceeds the concentration in 95% of the soil on Site. The consequence of these assumptions is that the estimated potential risk is representative of 0.0125% of the population (0.05 x 0.05 x 0.05 = 0.000125 x 100 = 0.0125%). Put another way, these assumptions overestimate risks for 9,999 out 10,000 people, or 99.99% of the population. Thus, the majority of people will have a much lower level of potential risk. The very conservative nature of the potential risks estimated by the risk assessment process is not generally recognized. In reality, the estimates are more conservative than outlined above, because usually more than three upper 95% assumptions are used to estimate potential risk(s).

Alternatively, if a single upper 95% assumption of the CSF is combined with average (50th percentile) assumptions for soil concentration and soil ingestion rate, the resulting estimates of potential risk still overpredict risk for 99% of the potentially exposed population. This is a conservative and health protective approach that substantially overestimates the "average" level and even the reasonable maximum level of potential risk.

The risk assessment approach used here employed upper 95% bounds or maxima for most RME exposure and toxicity assumptions. Thus, it produces estimates of potential risk two to three orders of magnitude greater than the risk experienced by the average member of the potentially exposed populations.

7.4.2 Risk to Sensitive Populations

The health risks estimated in the risk characterization generally apply to the receptors whose activities and locations were described in the exposure assessment. Some people will always be more sensitive than the average person and, therefore, will be at greater risk. Dose-response values used to calculate risk, however, are frequently derived to account for additional sensitivity of subpopulations (e.g., the uncertainty factor of 10 used to account for intraspecies differences). Therefore, it is unlikely that this source of uncertainty contributes significantly to the overall uncertainty of the risk assessment.

7.4.3 Central Tendency Exposure Risk Estimates

The RME scenario presented in this HHRA represents a very conservative scenario in which both upper-bound exposure assumptions as well as upper-bound EPCs are used. For RME scenarios where estimated risks are within or below the USEPA target levels, confidence is high that there are no unacceptable risks due to the conservative nature of the scenario. However, where risks within or above the target risk range of 10^{-6} to 10^{-4} are identified under the RME scenario, these risks may be overestimated. The assumptions regarding exposure frequency and duration in the RME risk estimates are very conservative. For example, while the agency default for working tenure is 25 years, the average occupational tenure for an industrial/commercial worker is 4.2 years. As another example, the agency RME estimate for adult shower duration is approximately 35 minutes (USEPA, 1997a). However, according to Burmaster (1998), less than 0.1% of the population showers for longer than 25 minutes. The use of conservative assumptions is likely to lead to an overestimate of potential risk. Furthermore, site-specific assumptions of exposure in the risk estimates do not represent actual opportunity for exposure at the site. Exposure frequency of an RME industrial/commercial worker is estimated at 250 days per year when there is currently no commercial or industrial activity at the site.

Therefore, a second scenario is developed to evaluate the potential risks under a more average scenario, the Central Tendency Exposure (CTE). Under this scenario, exposure assumptions are meant to reflect more typical exposures rather than upper-bound. CTE exposure assumptions were presented in Section 5.4 for all receptors and are listed in Tables 5-3 to 5-8. As requested by USEPA, the same EPCs used under the RME scenario are used under the CTE scenario, which is a very conservative approach. The only difference in the CTE risk estimate is that which results from reductions in exposure assumptions selected. For example, an on-site worker exposure frequency is reduced to 178 days/year (vs. 250) and exposure duration to 7 years (vs. 25). As described above, these parameters are still in excess of "average" exposures (USEPA, 1997a). Similarly, an angler exposure duration is reduced from 30 to 9 years in the CTE and exposure frequency from 52 to 26 days/year for surface water and sediment exposure. However, the sediment exposure pathway assumed the same adherence factor and ingestion rate for both RME and CTE. This is a very conservative approach to the quantification of a CTE estimate considering there was no allowance for a potentially more representative and less conservative EPC in the calculation.

CTE analyses were run for all scenarios (except the hypothetical future on-site resident) and results are discussed below for scenarios with RME cancer risks in excess of 10^{-6} or non-cancer hazard indices greater than 1 (on a toxic endpoint basis).

7.4.3.1 Trespasser

As discussed in Section 6.3.1, the potential RME cancer risk for the current and future trespasser exceeded 10^{-6} in all soil exposure areas due to direct contact with specific chemicals in surface soil (PCBs, potentially carcinogenic PAH, arsenic) and/or inhalation of benzene. The potential cancer risk for the trespasser also exceeded 10^{-6} in the Great Miami River and AOC 22 (Riparian Area) due to direct contact with benzo(a)pyrene in sediment and hydric soil, respectively. In addition, the potential RME hazard index for the trespasser exceeded a toxic endpoint HI of 1 in AOC 13 due to inhalation of naphthalene in ambient air. Therefore, CTE risk estimates were calculated for the trespasser exposure pathways using the exposure parameters and methods described in Section 5. The risk calculation spreadsheets are presented in Appendix D. Tables 7-2 and 7-3 present the CTE risk estimates. As shown in Table 7-2, based on the results of the CTE analyses, the areas with risks in excess of 10^{-6} and the associated COCs are as follows:

- PCBs in AOC 1 surface soil
- Benzene in AOC 13 combined soil

- Benzo(a)pyrene in AOC 13 surface soil (consistent with background)
- Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenz(a,h)anthracene in Great Miami River sediment (consistent with background)
- Benzo(a)pyrene in AOC 22 (Riparian Area) – (consistent with background)

As shown in Table 7-3, the potential CTE HI for the trespasser at AOC 13 exceeds 1 due to inhalation of naphthalene in ambient air (volatilized from combined soil). As previously noted, the EPC of naphthalene in AOC 13 soil (2860 mg/kg) exceeds the soil saturation limit for naphthalene of 375 mg/kg. USEPA guidance (2002b) states that the soil saturation limit represents an upper bound on the applicability of the volatilization factor model used to derive the soil to outdoor air concentrations. The guidance also states that for compounds that are solid at room temperature (i.e., naphthalene), concentrations above the soil saturation limit do not pose a significant inhalation risk. Therefore, the potential hazard for naphthalene is overstated (by a factor of 7.6) through the use of the statistically derived EPC rather than the soil saturation limit as the EPC. If the soil saturation limit were used as the EPC, the resulting RME hazard index would be 0.5 and naphthalene would not be identified as a COC in AOC 13 soil for the trespasser.

If the results of the background evaluation discussed in Section 7.1.3 are taken into account, including the discussion regarding the ubiquitous nature of PAH concentrations in Great Miami River sediment and AOC 7 sediment, as well as consideration of the soil saturation limit for naphthalene, the list of COCs and areas for the trespasser receptor assuming a risk level of 10^{-6} narrows to:

- PCBs in AOC 1 surface soil, and
- benzene in AOC 13 combined soil.

The trespasser direct contact exposure to site soil and River sediment (CTE) assumes 26 days/year (once a week) for 10 years, a skin contact area of 4033 cm^2 (hands, forearms, lower legs and feet) and an adherence factor of 0.05 and 0.28 mg/cm^2 for soil and sediment respectively. A trespasser on the site or in the Great Miami River is not likely to be barefoot and standing in the location of the most elevated PAH, PCB or benzene concentrations for this exposure period. Nor would they have a reason to reach underwater and grab or forage through the sediment. In the event that a trespasser were to happen upon an elevated sample location, it would be highly improbable that the same individual would happen upon the same location(s) during a subsequent event, and certainly not weekly for 10 years. Potentially carcinogenic PAH concentrations in other sediment samples along the reach of the Great Miami River adjacent to the Site are 10 to 100-fold lower than concentrations in these two samples. It is not known if the compounds are a result of historical site release, background conditions, or disturbance and deposition during a high water event. The presence of low levels of PAHs along the river may represent background conditions of the river system and be the result of sediment redistribution in the river during storm events. PAHs are present in upstream sediments at concentrations generally comparable to sediment concentrations in the reach adjacent to the Site. In summary, PAH concentrations in sediment are considered to be related to upstream conditions in the Great Miami River and not solely attributable to the Site.

If a cumulative target risk of 10^{-4} is used as the point of departure, no COCs or areas requiring further evaluation or remedial action are identified for the current/future trespasser receptor.

7.4.3.2 Recreational Angler

As discussed in Section 6.3.2, the potential RME cancer risk for the current and future recreational angler exceeded 10^{-6} in the Great Miami River, AOC 19 (where the COG pipeline passed beneath the Great Miami River), and the Riparian Area (AOC 22) due to direct contact with potentially carcinogenic PAH in sediment and hydric soil, and ingestion of PCBs in fish. In addition, the potential RME hazard index for the recreational angler exceeded a toxic endpoint HI of 1 due to mercury and PCBs in fish tissue from the Great Miami River. Therefore, CTE risk estimates were calculated for the recreational angler exposure pathways using the exposure parameters and methods described in Section 5. The risk calculation spreadsheets are presented in Appendix D. Tables 7-4 and 7-5 present the CTE risk estimates. As shown in Table 7-4, based on the results of the CTE analyses, the areas with risks in excess of 10^{-6} and the associated COCs are as follows:

- Benzo(a)anthracene, benzo(a)pyrene, and dibenz(a,h)anthracene in Great Miami River sediment (consistent with background)
- Benzo(a)pyrene in AOC 22 (Riparian Area) – (consistent with background)
- PCBs in fish tissue from the Great Miami River in the reach adjacent to Site, in the reach adjacent to AOC 19 (where the former COG pipeline passed beneath the Great Miami River), and in the upgradient reach (consistent with background)

As shown in Table 7-5, the potential CTE hazard index for the recreational angler in the Great Miami River exceeds 1 due to PCBs and mercury in fish in the reach adjacent to the Site, PCBs in the reach adjacent to AOC 19, and PCBs in the upgradient reach.

If a cumulative target risk of 10^{-4} is used as the point of departure, no carcinogenic COCs or areas requiring further evaluation or remedial action are identified for the current/future recreational angler receptor. However, consumption of fish still poses an unacceptable HI due to PCBs and mercury.

There is considerable conservatism in the models used to estimate fish tissue concentrations of bioaccumulatable compounds like PCBs and mercury due to uptake from sediment and surface water. The overconservatism of the BSAF approach used for PCBs was previously discussed in Section 7.3.2. This overconservatism is supported by actual measured PCB concentrations in fish samples collected from the Great Miami River in the vicinity of the site. Based on Ohio EPA fish monitoring data from 1993, 1998, and 2002 for carp, smallmouth bass, catfish and redhorse, total PCBs in fish tissue range from non-detect to approximately 1 mg/kg, well below modeled concentrations using USEPA's default BSAF. In addition, concentrations of PCBs in predicted in fish tissue using the BSAF approach in the upstream reach are about four-fold higher than predicted PCB fish tissue concentrations in the reach adjacent to the Site. In summary, PCBs in sediment and fish tissue appear to be related to background conditions in the Great Miami River and not the Site.

The potential hazard index for mercury is based on the assumption that mercury in surface water is present only as methyl mercury, which is a conservative assumption since mercury will be present in both organic and inorganic forms. The levels of mercury measured in the Great Miami River adjacent to and upstream of the Site represent total mercury. Since the methyl mercury BCF is intended to be applied to the dissolved fraction, applying the BCF to the total mercury concentration likely overestimates the fish tissue concentration. Research conducted by USGS scientists suggests that only about 6-7 percent of total mercury in the Great Miami River is present as methyl mercury (Krabbenhoft et al, 1999). This result indicates that the assumption that all of the mercury in the surface water is methyl mercury is very conservative. Further, the concentrations of total mercury measured adjacent to and upstream of the Site (0.01 to 0.19 ug/L) fall within the range of background levels measured in the Great and Little Miami River Basins (0.0003 to 1 ug/L) (Krabbenhoft, 1999).

USGS has also measured methyl mercury concentrations in fish tissue samples from the Great Miami River (USGS, 2001). Two smallmouth bass caught on the Great Miami River at Hamilton contained 0.113 mg/kg mercury (wet weight). This concentration is below the predicted fish tissue concentrations, which are 0.34 mg/kg for the reach on Great Miami River adjacent to AOC 19 and 1.54 mg/kg for the reach adjacent to the Site. These data suggest that the use of total mercury surface water concentrations with the methyl mercury BCF of 11,168 L/kg results in an overestimate of the fish tissue burden.

Last, mercury was identified as a COPC in Site soil only and not in Site groundwater or river sediment. Further, based on the background evaluation discussed in Section 7.1.2, mercury in surface soil is consistent with background. In summary, as with PCBs, mercury in surface water and fish tissue appear to be related to background conditions in the Great Miami River and not the Site.

7.4.3.3 Off-Site Resident

As discussed in Section 6.3.4, the potential RME risk for the off-site resident using water from the Hamilton North Wellfield exceeded USEPA's target risk range of 10^{-6} to 10^{-4} due primarily to benzo(a)pyrene, as well as arsenic and to a lesser extent benzene and BEHP. Dermal contact during bathing and ingestion of drinking water were the pathways of concern. Potential noncarcinogenic RME risk for the off-site resident also exceeded the target HI of 1 due to ingestion of naphthalene compounds and cyanide in drinking water. Therefore, CTE risk estimates were calculated for the off-site resident exposure pathways using the exposure parameters and methods described in Section 5. The risk calculation spreadsheets are presented in Appendix D. Tables 7-6 and 7-7 present the CTE risk estimates. As shown in Table 7-6, the potential CTE risk exceeds the upper end of the USEPA target range due to dermal contact with benzo(a)pyrene during bathing. Potential CTE risks associated with arsenic, benzene, and BEHP fall within the risk range of 10^{-6} to 10^{-4}.

As shown in Table 7-7, the potential CTE hazard index for the off-site resident exceeds 1 due to ingestion of cyanide, 2-methylnaphthalene, 1-methylnaphthalene, and naphthalene in groundwater used as drinking water.

The use of the on-site intermediate and deep wells to represent exposure point concentrations at the Hamilton North Wellfield is clearly a very conservative assumption, as attenuation and degradation of chemicals would occur between the Site and the wellfield. The RME scenario also assumed that someone is showering for approximately 35 minutes every day and used a model that likely overpredicts for lipophilic high molecular weight compounds like benzo(a)pyrene. Also, it is important to note that benzo(a)pyrene was detected only twice in the intermediate and deep on-site wells (at MW-8M and MW-27M). The detected concentration in MW-8M of 0.00016 mg/L is below the federal primary drinking water standard or Maximum Contaminant Level (MCL) for benzo(a)pyrene of 0.0002 mg/L. In addition, benzo(a)pyrene was not detected in MW-8M in the July 2008 sampling event. Most importantly, it should also be noted that benzo(a)pyrene was not detected (at a detection limit of 0.02 ug/L) in a water sample collected at the Hamilton North well on March 7, 1994 (Pesticides and Other Organic Chemicals, Sample Submission Report provided to Ohio EPA, March, 1994).

Table 7-8 presents a summary of analytical data for the eight COCs in the intermediate and deeps wells where these constituents were detected. As shown in Table 7-8, most of the elevated concentrations (and associated risks) are due to wells located in AOC 13 (e.g., MW-8M, MW-21M, and MW-27M). In the case of arsenic, the increased number of detects in 2008 relative to 2006 and higher arsenic risk is due to better detection limits. In addition, the off-site groundwater EPC for arsenic of 2.5 ug/L is below the arsenic MCL of 10 ug/L and consistent with the range of arsenic detected in upgradient wells MW-6, MW-10, and MW-14 (not detected to 4.7J ug/L). It should also be noted that arsenic is present in site soils at levels consistent with background in every AOC. It is unlikely that there is a source to site groundwater (above background) that would not also be found in site soils. It is likely that the source of arsenic in site groundwater is background levels of arsenic in soil.

There are two COCs with elevated concentrations in intermediate wells outside of AOC 13. One is for BEHP at MW-17M in AOC 1, however, the risk posed by BEHP is only 5×10^{-6}, which is well within the target risk range. The other elevated concentration outside of AOC 13 is for cyanide in MW-13M in Block A. However, this result was from 2006, and resampling of this well in 2008 resulted in a cyanide concentration that was 20-fold lower and no longer of human health concern. The remainder of the elevated concentrations of COCs are associated with wells in AOC 13, and MW-27M in particular.

In summary, the potentially unacceptable risk to the off-site resident receptor who is assumed to be exposed to intermediate and deep groundwater that has migrated off-site to the Hamilton North Wellfield is limited to AOC 13. Further, the estimated risk is overestimated, because it assumes that there is no attenuation or degradation of chemicals between the Site and the Hamilton North Wellfield. This is clearly an overly conservative assumption, especially for organics like benzene which are known to biodegrade in the environment, and for PAH compounds like benzo(a)pyrene, which adsorb tightly to soil particles and do not move appreciably in groundwater. The elevated concentrations of compounds like benzo(a)pyrene and cyanide in the groundwater sample from MW-27M, which was newly installed in June 2008, may indicate entrainment of particles in the sample and may not be representative of dissolved concentrations.

7.4.3.4 Future Construction Worker

As discussed in Section 6.3.5, potential RME risks for the future construction worker exceed 10^{-6} in all areas, and potential RME hazard indices exceed 1 (on a target organ basis) in AOC 1, Block A, and AOC 13. Lead in AOC 1 was also identified as a soil COC under the RME scenario for the construction worker. Therefore, CTE risk estimates were calculated for the construction worker exposure pathways using the exposure parameters and methods described in Section 5. The risk calculation spreadsheets are presented in Appendix D. Tables 7-9 and 7-10 present the CTE risk estimates. As shown in Table 7-9, the potential CTE risks for the future construction worker are in excess of 10^{-6} due to benzo(a)pyrene in AOC 1 combined soil, and benzo(a)anthracene, benzo(a)pyrene, and dibenz(a,h)anthracene in AOC 13 combined soil. However, none of the cumulative chemical risks exceed 10^{-5} under the CTE scenario.

As shown in Table 7-10, the potential CTE hazard index for the future construction worker exceeds 1 due to naphthalene in AOC 13 combined soil. If the soil saturation limit for naphthalene is used as the EPC in lieu of the statistically derived EPC (as previously discussed for the trespasser scenario), the CTE hazard index is less than 1, and naphthalene is not identified as a soil COC in AOC 13 under the CTE scenario.

As shown in Table 7-10a, lead is not identified as a COC in AOC 1 under the CTE scenario (no exceedance of the target blood lead level). In addition, as presented in Section 7.1.3, lead in combined soil in AOC 1 is shown to be consistent with background. Thus, lead is eliminated as a COC for AOC 1 soil.

7.4.3.5 Future On-Site Worker

As discussed in Section 6.3.6, potential risks and hazards from ingestion, dermal contact, and inhalation of soil and ingestion of groundwater are in excess of 10^{-6} and a HI of 1 in all soil areas. Therefore, CTE risk estimates were calculated for the future on-site worker exposure pathways using the exposure parameters and methods described in Section 5. The risk calculation spreadsheets are presented in Appendix D.

<u>Current Soil Scenario</u>

Tables 7-11 and 7-12 present the CTE risk estimates for the current soil scenario (i.e., contact with surface soil only). As shown in Table 7-11, the potential CTE risks exceed 10^{-6} for the following areas and COCs:

- AOC 1 – benzo(a)pyrene in surface soil (consistent with background), PCBs in surface soil, and benzene in combined soil
- AOC 2 – benzo(a)pyrene in surface soil (consistent with background)
- AOC 18/21 – benzo(a)pyrene in surface soil (consistent with background)
- AOC 19 – arsenic in surface soil (consistent with background)
- Block A – benzo(a)pyrene in surface soil (consistent with background)
- AOC 13 – benzo(a)pyrene in surface soil (consistent with background) and benzene in combined soil

It should be noted that the background evaluation indicated that arsenic and benzo(a)pyrene in surface soil at all AOCs are consistent with background. Thus, only PCBs in AOC 1 surface soil, benzene in AOC 1 combined soil, and benzene in AOC 13 combined soil are identified as soil COCs on the basis of the CTE analysis and a 10^{-6} risk level. It should be noted that the CTE risks posed by PCBs in surface soil and benzene in combined soil fall at the low end of the target risk range of 10^{-6} to 10^{-4} and would not be identified as soil COCs using 10^{-5} or 10^{-4} risk levels.

As shown in Table 7-11, a number of wells in the Southern Parcel and AOC 13 have COCs that pose hypothetical drinking water risks in excess of 10^{-6}, and a few wells in AOC 13 have CTE risks in excess of 10^{-4} The key groundwater COCs in these two areas are arsenic, benzene, and several potentially carcinogenic PAH compounds. However, as previously noted, use of on-site groundwater as a future drinking water resource will be prohibited via a deed restriction.

As shown in Table 7-12, the potential CTE HI for the future on-site worker exceeds 1 at AOC 1 due to inhalation of naphthalene in ambient air (volatilized from combined soil) and direct contact with PCBs in surface soil. In addition, the potential CTE HI for the future on-site worker exceeds 1 at AOC due to inhalation of naphthalene in ambient air (volatilized from combined soil). Thus, naphthalene and PCBs in AOC 1 and naphthalene in AOC 13 combined soil are identified as COCs on the basis of the CTE analysis. Note that the HI for naphthalene still exceeds 1 if the soil saturation limit is used as the EPC for the soil to air volatilization pathway.

Future Soil Scenario

Tables 7-13 and 7-14 present the CTE risk estimates for on-site worker for the future soil scenario (i.e., contact with both surface soil and subsurface soil that is brought to the surface in the future). As shown in Table 7-13, the potential CTE risks exceed 10^{-6} for the following areas and COCs:

- AOC 1 – PCBs in surface soil and benzene in combined soil
- AOC 18/21 – benzo(a)pyrene in surface soil (consistent with background)
- AOC 13 – benzo(a)pyrene in surface soil (consistent with background) and benzene in combined soil

Based on a review of benzo(a)pyrene soil concentrations, potential carcinogenic risk from benzo(a)pyrene in combined soil is driven by surface soil concentrations. As noted above, the background evaluation indicated that benzo(a)pyrene in surface soil at all AOCs is consistent with background. Thus, only PCBs and benzene in AOC 1 combined soil and benzene in AOC 13 combined soil are identified as COCs on the basis of the CTE analysis and a 10^{-6} risk level. It should be noted that the CTE risks posed by PCBs and benzene in combined soil fall at the low end of the target risk range of 10^{-6} to 10^{-4} and would not be identified as soil COCs using 10^{-5} or 10^{-4} risk levels.

As shown in Table 7-13, several wells in the Southern Parcel and AOC 13 have COCs that pose hypothetical drinking water risks in excess of 10^{-6}, and a few wells in AOC 13 have CTE risks in excess of 10^{-4}. The primary groundwater COCs in these two areas are arsenic, benzene, and several potentially carcinogenic PAH compounds. However, as previously noted, use of on-site groundwater as a future drinking water resource will be prohibited via a deed restriction.

As shown in Table 7-14, the potential CTE HI for the future on-site worker exceeds 1 at AOC 1 and AOC 13 due to inhalation of naphthalene in ambient air (volatilized from combined soil). Thus, naphthalene in AOC 1 and AOC 13 combined soil is identified as a COC on the basis of the CTE analysis. As shown in Table 7-14, several wells in AOC 13 have COCs with hazard indices in excess of 1, including cyanide, benzene, dibenzofuran, naphthalene, and 2-methylnaphthalene.

7.5 Summary of Sources of Uncertainty in Human Health Risk Assessment

The large number of assumptions made in the risk characterization introduces uncertainty in the results. While this could potentially lead to underestimates of potential risk, the use of numerous conservative (i.e., protective of human health) assumptions, as was done here, results in overestimates of potential risks. Any one person's potential exposure and subsequent risk are influenced by all the parameters mentioned above and will vary on a case-by-case basis. Despite inevitable uncertainties associated with the steps used to derive potential risks, the use of numerous health-protective assumptions will most likely lead to a very large overestimate of potential risks from the Site. Moreover, when evaluating risk assessment results, it is important to put the risks into perspective. For example, the American Cancer Society (ACS) estimates that the lifetime probability of contracting cancer in the U.S. is 1 in 2 for men and 1 in 3 for women (ACS, 2004). The results of the risk assessment must be carefully interpreted considering the uncertainty and conservatism associated with the analysis, especially where Site management decisions are made.

For the baseline HHRA conducted for the Armco Hamilton Plant Site, a number of conservative assumptions and methods were used resulting in very health-protective estimates of potential site-specific risk. These health-protective assumptions include intentionally stringent toxicity values, upper-bound exposure point concentrations, and reasonable maximum exposure (RME) assumptions, which consequently result in estimated risks that are biased high. In addition, use of the low end of USEPA's target risk range of 10^{-6} to 10^{-4} to identify COCs results in inclusion of chemicals and areas that may not warrant remedial action and have been shown to be consistent with background in levels in site soil and upstream river sediment.

Some of the key overconservatisms were addressed in this Uncertainty Analysis, including consideration of consistency with background and central tendency exposure assumptions, as well as alternate target risk levels (i.e., 10^{-5} and 10^{-4}). Table 7-20 summarizes potential COCs identified in all Site media of interest based on the results of the RME risk characterization using a 10^{-6} risk level. Table 7-20 also identifies which chemicals may be eliminated as COCs based on the results of the quantitative and qualitative background evaluations and the CTE analyses. A close inspection of Table 7-20 reveals that the majority of RME COCs in soil are eliminated when the results of the background evaluations are taken into account. When the results of the CTE analysis are also considered, several additional COCs in soil are eliminated, as well as select COCs in river sediment and surface water and in Site groundwater. As shown in Table 7-20, the COCs and areas remaining in each medium of interest after accounting for the results of the background and CTE evaluations are as follows at a 10^{-6} risk level:

Soil

- Benzene in AOC 1 and AOC 13 combined soil;
- Select potentially carcinogenic PAH compounds in AOC 1, Southern Parcel and AOC 13 subsurface soil (potentially carcinogenic PAH in surface soil are consistent with background in all soil exposure areas);
- Naphthalene in AOC 1 and AOC 13 combined soil;
- PCBs in AOC 1 surface soil;

Groundwater

- Various inorganics and organics in AOC 13 shallow, intermediate and deep groundwater used in the hypothetical future on-site worker drinking water scenario;
- Various inorganics and organics in AOC 13 intermediate and deep groundwater (assumed to migrate off-site to the Hamilton North Wellfield without any dilution or attenuation) used in the off-site resident drinking water scenario.

All of the potential COCs identified based on the results of the RME risk characterization and summarized in Table 7-20 (including those that are consistent with background) are carried forward into the development of remedial goal options (RGOs), which are presented in Section 8.0. However, the impact of the background evaluation on the risk results for this Site should not be underestimated, as it is a critical factor in interpreting the significance of the HHRA findings. As previously noted, USEPA guidance does not require remediation to levels below background (USEPA, 2002f). Further, in correspondence to AK Steel dated August 26, 2008, USEPA confirmed the approach of taking background issues into consideration in the Uncertainty Analysis, and addressing site-specific background issues at the end of the risk characterization (USEPA, 2008b).

When site-specific background is factored into the RME risk results, site risks drop below 10^{-6} in several exposure areas including AOC 2, AOC 18 & 21, AOC 19, the Riparian Area (AOC 22), and AOC 7 (intermittent stream). When upgradient and regional concentrations of PCBs in Great Miami River sediment and mercury in Great Miami River surface water are considered, potential fish consumption risks for a recreational angler also drop to within the range of the target risk benchmarks. When upstream concentrations of PAHs in the Great Miami River sediment are taken into account, PAHs in sediment samples adjacent to the Site can in general be shown to be due to upstream conditions and not solely attributable to the Site.

Thus, it is critical that background conditions be carefully considered when interpreting the HHRA results for the Site.

8.0 Remedial Goal Options

This section discusses the derivation of remedial goal options (RGOs) for the constituents identified as COCs in Section 7.0. As previously discussed, for potentially carcinogenic risk results, COCs are identified as those COPCs that cause an exceedance of the target risk level of 10^{-6}. While remedial action may not be warranted where potential risks exceed 10^{-6} but are below 10^{-4}, for this HHRA, any COPC that causes an exceedance of the 10^{-6} risk level for a particular receptor is designated a COC. The target risk levels used for the identification of COCs are based on USEPA direction for the Site. As previously noted, USEPA provides the following guidance (USEPA, 1991a):

> "Where the cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4}, and the non-carcinogenic hazard quotient is less than 1, action generally is not warranted unless there are adverse environmental impacts." and,
>
> "The upper boundary of the risk range is not a discrete line at 1×10^{-4}, although EPA generally uses 1×10^{-4} in making risk management decisions. A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions."

Therefore, while COCs have been identified using a 10^{-6} risk level, further risk management determinations will be made and remedial action may not be warranted for all COCs.

For noncarcinogenic hazard results, COCs are identified as those COPCs that cause an exceedance of the toxic-endpoint specific HI of one. RGOs have been calculated for those COPCs identified as COCs.

Where RGOs are calculated, the following formula is used:

$$RGO = \frac{EPC \times Allowable\ (Risk\ or\ HQ)}{Calculated\ (Risk\ or\ HQ)}$$

The EPC is the exposure point concentration used in the risk calculations. As discussed with USEPA, RGOs for potentially carcinogenic COCs are derived for three target risk levels (10^{-6}, 10^{-5}, and 10^{-4}). This approach provides a range of RGOs that fall within the USEPA target risk range.

The allowable HQ per noncarcinogenic constituent is 1 minus the HQ from other constituents with similar toxic endpoints. When there is more than one noncarcinogenic constituent identified as COCs for a given scenario, the target HI of 1 (minus the total HI from other constituents) is apportioned between the identified COCs. This apportioning can be done in any manner, though most commonly it is done equally between all of the COCs.

Where federal drinking water standards are available for a COC in groundwater assumed to be used as drinking water, the drinking water standard (e.g., Maximum Contaminant Level (MCL)) is identified as the RGO, and the COC is not included in RGO calculations.

8.1 Current and Future Trespasser

Table 8-1 identifies the areas and COCs for which RGOs were derived based on the results of the baseline HHRA for the current and future trespasser. As shown in Table 8-1, all but two RGOs are based on potential cancer risk. RGOs for PCBs in AOC 1 surface soil and naphthalene in AOC 13 combined soil are based on potential noncarcinogenic effects. While PCBs have both potential carcinogenic and noncarcinogenic effects, the RGOs based on noncarcinogenic effects are more stringent.

Table 8-1 also identifies COCs that were found to be consistent with background or shown to not pose an unacceptable risk under the CTE analysis. This includes all of the potentially carcinogenic PAH compounds and arsenic in surface soil. The remaining COCs highlighted in Table 8-1 represent COCs remaining after consideration of background and CTE results. This includes a subset of potentially carcinogenic PAH in sediment at the Great Miami River and AOC 7 (intermittent stream), PCBs and benzene in AOC 1 soil, and benzene and naphthalene in AOC 13 soil.

8.2 Current and Future Recreational Angler

Table 8-2 identifies the areas and COCs for which RGOs were derived based on the results of the baseline HHRA for the current and future trespasser. As shown in Table 8-2, the COCs requiring RGOs include several potentially carcinogenic PAH in Great Miami River sediment adjacent to the Site. In addition, RGOs are required for PCBs in Great Miami River sediment and mercury in Great Miami River surface water in both reaches due to potential bioaccumulation to fish tissue. Table 8-2 identifies potentially carcinogenic PAH in AOC 22 (Riparian Area) surface soil as consistent with background.

8.3 Future Construction Worker

Table 8-3 identifies the areas and COCs for which RGOs were derived based on the results of the baseline HHRA for the future construction worker. As shown in Table 8-3, most RGOs are based on potential cancer risk. RGOs for PCBs, lead and naphthalene in AOC 1 soil, manganese in Block A soil, and naphthalene in AOC 13 soil are based on potential noncarcinogenic effects.

Lead was identified as a COC in AOC 1 combined soil, based on the results of the Adult Lead Model (ALM) (USEPA, 1996c, spreadsheet version date 5/19/03). Using the PRG calculator in the ALM, soil lead PRGs of 1040 mg/kg for a homogeneous population and 657 mg/kg for a heterogeneous population were derived. EPA's screening level for soil lead at commercial/industrial (i.e., non-residential) sites is 800 mg/kg, which falls near the middle of the two ALM PRGs http://www.epa.gov/superfund/lead/almfaq.htm#screening). Therefore, 800 mg/kg is proposed as the RGO for lead in soil in AOC 1. However, as discussed in Section 7.1.3, lead in combined soil was shown to be consistent with background, and thus should not be identified as a soil COC for AOC 1.

8.4 Future On-site Worker

Tables 8-4 and 8-5 identify the areas and COCs for which RGOs were derived based on the results of the baseline HHRA for the future on-site worker, current and future soil scenarios, respectively. As shown in Tables 8-4 and 8-5, all but a limited number of RGOs are based on potential cancer risk. RGOs for PCBs in AOC 1 surface soil, and naphthalene in AOC 1 and AOC 13 (current scenario only) combined soil are based on potential noncarcinogenic effects.

Tables 8-4 and 8-5 also identify COCs that were found to be consistent with background or shown to not pose an unacceptable risk under the CTE analysis. This includes all of the potentially carcinogenic PAH compounds and arsenic in surface soil in all areas (Table 8-4), arsenic in combined soil in all areas (Table 8-5), and potentially carcinogenic PAH compounds in combined soil in AOC 2, AOC 18 & 21, AOC 19, and Block A (Table 8-5). The remaining COCs highlighted in Tables 8-4 and 8-5 represent COCs remaining after consideration of background and CTE results. This includes PCBs in AOC 1 surface soil, and benzene and naphthalene in AOC 1 and AOC 13 combined soil. One or more potentially carcinogenic PAH are identified as COCs in subsurface soil only in AOC 1, Southern Parcel, and AOC 13 (surface concentrations are consistent with background).

Table 8-6 identifies all groundwater wells and COCs for which RGOs were derived based on the results of the baseline HHRA for the future on-site worker who is assumed to drink on-site groundwater. As shown in Table 8-6, all but one well and COC are located within the Southern Parcel and the majority of wells with groundwater COCs are located within AOC 13. Only arsenic and benzo(a)pyrene are identified as groundwater COCs in AOC 1 and the Southern Parcel. As shown in Table 8-6, the groundwater EPCs used in the HHRA for arsenic and benzo(a)pyrene for AOC 1 and Southern Parcel are below their respective MCLs. Where MCLs are available, they are identified as the RGOs. As previously noted, use of on-site groundwater as a future drinking water resource will be prohibited via a deed restriction.

8.5 Current and Future Off-site Resident

Table 8-7 identifies the COCs for which RGOs were derived based on the results of the baseline HHRA for the off-site resident who is assumed to drink groundwater from the Hamilton North Wellfield. MCLs are available for five of the eight COCs, and are therefore identified as the RGOs for these compounds (arsenic, benzene, cyanide, benzo(a)pyrene, and BEHP). Risk-based RGOs based on potential noncarcinogenic effects are identified for the other three COCs, which are the naphthalene compounds (naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene). As previously noted, the potentially unacceptable risk to the off-site resident receptor who is assumed to be exposed to intermediate and deep groundwater that has migrated off-site to the Hamilton North Wellfield is limited to wells located within AOC 13. Further, the estimated risk is overestimated, because it assumes that there is no attenuation or degradation of chemicals between the Site and the Hamilton North Wellfield.

9.0 Summary and Conclusions

This document presents the baseline human health risk assessment (HHRA) for the AK Steel Corporation former Armco Hamilton Plant (AHP) (the "Site") in New Miami, Ohio. This HHRA has been conducted in accordance with the RI/FS Work Plan and applicable agency guidance, and in accordance with responses to USEPA comments on the draft HHRA. The HHRA has been developed to satisfy the human health risk assessment components of the objectives stipulated by the Administrative Order on Consent (AOC; EPA Docket No. V-W-'02-C-692) entered into by the USEPA and AK Steel and the associated Scope of Work (SOW).

The risk assessment results are summarized by step below.

9.1 Hazard Identification

This step of the risk assessment involves compiling and summarizing Site data, and selecting COPCs based on a series of screening steps. Site data and background data are available for the following media:

- Surface soil (0-2 ft)
- Subsurface soil (> 2 ft)
- Hydric soil
- Groundwater
- Sediment
- Surface water

The data for each area and medium were summarized for use in the COPC screening and generation of summary statistics.

COPC screening was conducted based on essential nutrient status, comparison against risk-based screening levels, and low frequency of detection. Chemicals in various media with concentrations greater than these screening levels were retained for quantitative evaluation in the risk assessment. Two chemicals in soil were eliminated on the basis of low frequency of detection. A total of 54 compounds were identified as COPCs for the baseline HHRA.

9.2 Dose-Response Assessment

The purpose of the dose-response assessment is to identify the types of adverse health effects a chemical may potentially cause, and to define the relationship between the dose of a chemical and the likelihood or magnitude of an adverse effect (response).

Adverse effects are defined by USEPA as potentially carcinogenic or noncarcinogenic (i.e., potential effects other than cancer). Both sets of potential health effects were evaluated in the risk assessment. Dose-response relationships are defined by USEPA. The dose-response values for potentially carcinogenic effects are termed Cancer Slope Factors (CSFs) or Unit Risk Factors, and dose-response values for noncarcinogenic effects are termed Reference Doses (RfDs) or Reference Concentrations (RfCs). These values are available from USEPA sources, such as USEPA's Integrated Risk Information System (IRIS), an on-line computer database (USEPA, 2008a), the National Center for Environmental Assessment (NCEA), the Health Effects

Assessment Summary Tables (HEAST) (USEPA, 1997b), and other non-USEPA sources including California EPA and the Agency for Toxic Substances and Disease Registry (ATSDR).

Dose-response values are available for inhalation and oral exposures. COPCs were also evaluated quantitatively for the dermal exposure pathway using appropriate dermal adjustments. USEPA Region 5 was also contacted and the agency provided current provisional dose-response information for COPCs lacking values from the hierarchy of sources including IRIS and California EPA. The provisional dose-response values provided by USEPA were used in the revised baseline HHRA.

9.3 Exposure Assessment

The purpose of the exposure assessment is to predict the magnitude and frequency of potential human exposure to each of the COPCs retained for quantitative evaluation in the HHRA. The first step in the exposure assessment process is the characterization of the setting of the Site and surrounding area. Current and potential future Site uses and potential receptors (i.e., people who may contact the impacted environmental media of interest) are then identified. Potential exposure scenarios appropriate to current and potential future Site uses and receptors are then developed. Those potential exposure pathways for which COPCs are identified and are judged to be complete were evaluated quantitatively in the risk assessment.

9.3.1 Identification of Potential Exposure Scenarios

Based on current and potential future land use, the following receptors were evaluated:

- Future On-site Worker - The future on-site worker is assumed to contact COPCs in surface soil via incidental ingestion and dermal contact, and inhale COPCs via soil-derived fugitive dusts and volatiles in ambient air. A second scenario, not discussed in the work plan, in which it is assumed that subsurface soils are brought to the surface is also evaluated. In the second scenario, all soils are treated as surface soils. The future on-site worker is also evaluated for potential exposure to COPCs in on-site groundwater used as a source of drinking water. [Note that no one is currently using on-site groundwater as drinking water and a deed restriction will be proposed which will not allow the installation of drinking water wells on-site.]

- Future Construction Worker - The future construction/utility worker is assumed to contact COPCs in surface and subsurface soil down to 10 ft bgs (incidental ingestion, dermal contact, inhalation of particulates and volatiles in excavation air). Groundwater is not a medium of concern for the construction worker, because depth to groundwater is greater than 10 feet bgs (generally in the range of 20 to 40 feet bgs) and beyond typical excavation depths.

- Current and Future Trespasser – The trespasser, who is a child of 7 to 16 years of age, is assumed to contact COPCs in surface soil via incidental ingestion and dermal contact, and inhale COPCs via soil-derived fugitive dusts and volatiles in ambient air. The trespasser is also assumed to contact COPCs in sediment and surface water while wading in or playing near the intermittent stream (AOC 7) and the Great Miami River, as well as COPCs in hydric soil in the Riparian Area (AOC 22).

- Current and Future Recreational Angler – The recreational angler is assumed to be exposed to bioaccumulatable COPCs through ingestion of fish from the Great Miami River. The recreational angler is also assumed to contact COPCs in surface water and sediment in the Great Miami River, as well as COPCs in hydric soil in the Riparian Area (AOC 22).

- Current and Future Off-site Resident – It is assumed that on-site groundwater from the intermediate and deep groundwater may reach the Hamilton North Wellfield, located to the south of the Site across the Great Miami River. The current and future off-site resident is assumed to use groundwater from the Hamilton North Well as drinking water and for bathing/showering. Both adult and child residents were evaluated. In addition to the drinking water pathway discussed in the work plan, an additional pathway is included in the risk assessment to evaluate potential concentrations of VOCs in air during showering or bathing.

- Hypothetical Future On-site Resident – At the request of USEPA, it was assumed that the Site could be developed for residential purposes in the future. This is unlikely to occur, and it is anticipated that a deed restriction will be obtained to prohibit future residential development of the Site. However, for the purposes of this Baseline HHRA, the hypothetical future on-site resident is assumed to contact COPCs in surface soil via incidental ingestion and dermal contact, and inhale COPCs via soil-derived fugitive dusts and volatiles in ambient air. The hypothetical future on-site resident is also assumed to inhale volatile COPCs that may migrate from groundwater to indoor air inside a future residence. Potential exposure via inhalation of volatiles released from groundwater for household tasks was discussed qualitatively in Section 6.3.3.

9.3.2 Quantification of Potential Exposures

To estimate the potential risk to human health that may be posed by the presence of COPCs at the Site, it was first necessary to estimate the potential exposure dose of each COPC. The exposure dose is estimated for each chemical via each exposure pathway by which the receptor is assumed to be exposed. Exposure dose equations combine the estimates of chemical concentration in the environmental medium of interest with assumptions regarding the type and magnitude of each receptor's potential exposure to provide a numerical estimate of the exposure dose. The exposure dose is defined as the amount of COPC taken into the receptor and is expressed in units of milligrams of COPC per kilogram of body weight per day (mg/kg-day).

USEPA exposure assumptions were used when available. Both Reasonable Maximum Exposure (RME) and Central Tendency Exposure (CTE) exposure assumptions were developed. The RME analysis represents a very conservative scenario in which both upper-bound exposure assumptions as well as upper-bound EPCs are used. For RME scenarios where estimated risks are within or below the USEPA target levels, confidence is high that there are no unacceptable risks due to the conservative nature of the scenario. However, where risks within or above the target risk range of 10^{-6} to 10^{-4} are identified under the RME scenario, these risks may be overestimated. Therefore, a CTE analysis was performed to estimate potential risks under an average scenario. Under CTE scenarios, exposure assumptions are meant to reflect more typical exposures rather than upper-bound. The results of the CTE analysis were presented in the uncertainty section of this document.

In order to quantify exposures, it is also necessary to estimate chemical concentrations in the various exposure media. Measured data are available for surface soil, subsurface soil, groundwater, surface water, and sediment. For soil, sediment, and surface water, the exposure point concentration is defined as the lower of the site-wide maximum or 95% UCL on the arithmetic mean concentrations (USEPA, 2002a) for the RME scenario. As requested by USEPA, RME EPCs were also used for the CTE analyses, which is a conservative approach. For on-site groundwater, the maximum detected concentration in each well was selected as the EPC for that well. For off-site groundwater at the Hamilton North Wellfield, UCLs for COPCs in on-site intermediate and deep wells were conservatively assumed to represent exposure point concentrations at the Hamilton North Wellfield, without accounting for any dilution or attenuation.

Other pathways required modeling to derive exposure point concentrations. These pathways include:

- Volatilization from groundwater to indoor air;
- Generation of particulates (fugitive dust) and volatiles from undisturbed soils;
- Generation of particulates (fugitive dust) and volatiles during construction activities; and
- Prediction of fish tissue concentrations for bioaccumulatable COPCs in surface water and sediment; and

- Volatilization of COPCs in groundwater while shower/bathing.

9.4 Risk Characterization

The results of the exposure assessment are combined with the results of the dose-response assessment to derive quantitative estimates of risk, or the probability of adverse health effects following assumed potential exposure to the COPCs. Using the exposure point concentrations derived in the exposure assessment, each exposure pathway for each receptor was evaluated for both potential carcinogenic and noncarcinogenic effects.

The assumptions regarding intakes, exposure frequency and duration in the RME risk estimates are very conservative. The use of conservative assumptions is likely to lead to an overestimate of potential risk. Furthermore, site-specific assumptions of exposure in the risk estimates do not represent actual opportunity for exposure at the Site. For example, the exposure frequency of an RME industrial/commercial worker is estimated at 250 days per year when there is currently no commercial or industrial activity at the Site. Consistent with USEPA guidance, a second scenario was considered in this risk assessment to evaluate the potential risks under a more average scenario, the Central Tendency Exposure (CTE). Under this scenario, exposure assumptions are meant to reflect more typical exposures rather than upper-bound. As requested by USEPA, the same EPCs used under the RME scenario were used under the CTE scenario. The only difference in the CTE risk estimate is that which results from reductions in exposure assumptions selected. This is a very conservative approach, considering there was no allowance for a potentially more representative and less conservative EPC in the calculation.

Tables 9-1 and 9-2 present a summary of the results of the baseline HHRA for the RME and CTE scenarios, respectively. Based on the results of the RME risk characterization, CTE analyses were run for all scenarios, except for the hypothetical future on-site resident, as part of the uncertainty analysis. Because of potentially unacceptable carcinogenic and noncarcinogenic risks for the hypothetical future on-site resident in all areas, further evaluation of this receptor scenario was not performed. In addition, it is anticipated that a deed restriction prohibiting future residential use of the Site will be obtained.

A quantitative background evaluation was also performed as part of the uncertainty analysis for key constituents in soil (i.e., specific metals contributing most to total risk and potentially carcinogenic PAH). Background was also qualitatively addressed for the intermittent stream (AOC 7) and the Great Miami River. The results of the background evaluations are critical in interpreting the HHRA findings for this Site, and are discussed in the summary of results below. As previously noted, USEPA guidance does not require remediation to levels below background (USEPA, 2002f). Further, in correspondence to AK Steel dated August 26, 2008, USEPA confirmed the approach of taking background issues into consideration in the Uncertainty Analysis, and addressing site-specific background issues at the end of the risk characterization (USEPA, 2008b).

9.4.1 Carcinogenic Risk Characterization

The purpose of carcinogenic risk characterization is to estimate the upper-bound likelihood, over and above the background cancer rate, that a receptor will develop cancer in his or her lifetime as a result of exposure to a chemical in environmental media at the Site. The results are compared to the USEPA's target risk range of 10^{-4} to 10^{-6}. While remedial action might not be warranted where potential risks exceed 10^{-6} but are below 10^{-4}, for this HHRA, any COPC that causes an exceedance of 10^{-6} risk level for a particular receptor is designated a COC. The target risk levels used for the identification of COCs are based on USEPA direction for the Site. It should be noted that USEPA provides the following guidance (USEPA, 1991a):

> "Where the cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4}, and the non-carcinogenic hazard quotient is less than 1, action generally is not warranted unless there are adverse environmental impacts." and,

"The upper boundary of the risk range is not a discrete line at 1 x 10^{-4}, although EPA generally uses 1 x 10^{-4} in making risk management decisions. A specific risk estimate around 10^{-4} may be considered acceptable if justified based on site-specific conditions."

Therefore, while COCs have been identified using a 10^{-6} risk level, further risk management determinations will be made and remedial action may not be warranted for all COCs. To aid in the interpretation of the results of the baseline HHRA, potential COCs are also identified using 10^{-5} and 10^{-4} risk levels (with consideration of cumulative Site risk at 10^{-4}). Tables 9-3, 9-4, and 9-5 present summaries of potential COCs for each medium of interest, after accounting for consistency with background, at risk levels of 10^{-6}, 10^{-5}, and 10^{-4}, respectively. These tables also identify which potential COCs may be eliminated based on the results of the CTE analyses (shaded results).

Summary of RME Results

Table 9-1 presents a summary of the results of the baseline HHRA for the RME scenarios. As shown in Table 9-1, potential RME carcinogenic risks in excess of 10^{-6} were identified for all receptors and areas. As shown in Table 9-3, after accounting for consistency with background, the exposure areas and potentially carcinogenic COCs in soil based on the results of the RME analysis and a 10^{-6} risk level are as follows:

- AOC 1 – benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and PCBs

- AOC 2 - PCBs

- AOC 18 & 21 – PCBs

- Block A – benzene

- Southern Parcel – benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene

- AOC 13 – benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and PCBs

Benzo(a)pyrene was identified as a potential COC in AOC 7 (intermittent stream) sediment, based on a potential direct contact risk to a trespasser of 3 x 10^{-6}, which falls at the low end of the target risk range. AOC 7 is principally a storm water drainage ditch and is dry much of the year. As such, the substrate may more accurately be considered hydric soil than sediment. Due to the limited number of AOC 7 "sediment" samples, a quantitative background evaluation could not be performed. However, as discussed in the Uncertainty Analysis, based on a qualitative comparison of potentially carcinogenic PAH compounds detected in AOC 7 and in background surface soil samples, it is reasonable to conclude that the levels of carcinogenic PAH detected in AOC 7 substrate are consistent with typical background PAH concentrations in surface soil impacted by historical anthropogenic activities, including the nearby railroad.

Based on qualitative evaluations of PAH, PCBs, and mercury in Great Miami River sediment and surface water, it is concluded that the presence of these compounds in the Great Miami River is attributable to background conditions and upstream sources.

Based on the results of the RME analysis of the hypothetical future on-site worker's use of on-site groundwater as drinking water, there are a number of wells with COCs posing risks in excess of 10^{-6}. As previously stated, a restriction against groundwater use on-site will be obtained. Therefore, while potential groundwater COCs are identified for completeness, remedial actions may not be warranted because an institutional control will prevent the exposure thereby eliminating any potentially unacceptable risks. Potential COCs were identified in the following wells:

- Northern Parcel – MW-17S (arsenic only, at a concentration below its federal drinking water standard or maximum contaminant level (MCL))
- Southern Parcel – MW-1S, MW-2S, MW-3D, MW-3S, MW-4M, MW-4S, MW-7M, MW-19S, MW-23S (arsenic in all but one well and benzo(a)pyrene in two wells, all at concentrations below their MCLs)
- AOC 13 – MW-8M, MW-8S, MW-9M, MW-9S, MW-20M, MW-20S, MW-21S, MW-21S, MW-27M, MW-27S, MW-28S, MW-29S, MW-31S

Primary risk drivers in groundwater include arsenic, benzene, and potentially carcinogenic PAH. The majority of wells with groundwater COCs are located within AOC 13. In fact, only arsenic and benzo(a)pyrene are identified as groundwater COCs in AOC 1 and the Southern Parcel, and groundwater EPCs used in the HHRA for these two COCs and areas were below their respective MCLs.

Based on the results of the RME analysis of the off-site resident at the Hamilton North Wellfield, four potentially carcinogenic COCs were identified – arsenic, benzene, benzo(a)pyrene, and BEHP. Based on a review of the intermediate and deep groundwater data used in this scenario, potentially unacceptable risk to the off-site resident receptor is limited to wells located within AOC 13. The estimated risk is also overestimated, because it assumes that there is no attenuation or degradation of chemicals between the Site and the Hamilton North Wellfield. This is clearly an overly conservative assumption, especially for organics like benzene which are known to biodegrade in the environment, and for PAH compounds like benzo(a)pyrene, which adsorb tightly to soil particles and do not move appreciably in groundwater.

As shown in Tables 9-4 and 9-5, which summarize potential COCs at 10^{-5} and 10^{-4} risk levels, respectively, potentially carcinogenic RME COCs are limited to:

- One or more potentially carcinogenic PAH in soil at AOC 1, Southern Parcel and AOC 13,
- Benzene in soil at AOC 1 and AOC 13 (at 10^{-5} risk level only),
- PCBs in soil at AOC 1, and
- Arsenic, cyanide, and multiple organics in groundwater in AOC 13 wells (for both on-site and off-site drinking water scenarios).

<u>Summary of CTE Results</u>

Table 9-2 presents the results of the baseline HHRA for the CTE scenarios. Based on the results of the CTE analysis, COCs with potential carcinogenic risks in excess of 10^{-6} were identified for all receptors and most areas. However, based on the CTE analysis, considerably fewer carcinogenic COCs are identified at the 10^{-6} risk level as shown by the shaded cells in Table 9-3.

Tables 9-4 and 9-5 summarize COCs at risk levels of 10^{-5} and 10^{-4} (cumulative for Site), respectively. The shaded cells represent COCs that may be eliminated based on the results of the CTE analysis at each target risk level. The impact of the CTE analysis is significant for the soil and sediment exposure pathways:

- As shown in Table 9-4, at a 10^{-5} risk level, all but benzo(a)pyrene in AOC 1 and AOC 13 soil, and benzo(a)pyrene and PCBs in Great Miami River sediment are eliminated as COCs based on the results of the CTE analysis. Benzo(a)pyrene and PCBs in the Great Miami River sediment are considered to be consistent with background (upstream conditions).
- As shown in Table 9-5, at a 10^{-4} cumulative Site risk level, all potentially carcinogenic COCs and PCBs in soil and sediment are eliminated based on the results of the CTE analysis. As noted above, potentially carcinogenic PAH and PCBs in Great Miami River sediment are considered to be consistent with background (upstream conditions).

Based on the results of the CTE analysis and using a cumulative Site risk of 10^{-4}, only one noncarcinogenic COC remains in soil (naphthalene in AOC 1 and AOC 13). Several COCs remain in AOC 13 groundwater. The results of the noncarcinogenic risk characterization for the Site are discussed below.

9.4.2 Noncarcinogenic Risk Characterization

The potential for exposure to a chemical to result in adverse noncarcinogenic health effects is estimated for each receptor by comparing the Chronic Average Daily Dose (CADD) for each COPC with the RfD for that COPC. The resulting ratio, which is unitless, is known as the Hazard Quotient (HQ) for that chemical.

The total Hazard Index (HI) is calculated for each exposure pathway by summing the HQs for each individual chemical. The total Site HI is calculated for each potential receptor by summing the HIs for each pathway associated with the receptor. If the total Site HI is greater than one for any receptor, a more detailed evaluation of potential noncarcinogenic effects based on specific health endpoints is performed (USEPA, 1989). For noncarcinogenic hazard index results, COCs are identified as those COPCs that cause an exceedance of the toxic-endpoint specific HI of one.

<u>Summary of RME Results</u>

Table 9-1 presents the results of the baseline HHRA for the RME scenarios. As shown in Table 9-1, potential RME noncarcinogenic HI in excess of 1 on a target organ basis were identified for only specific receptors and areas. As shown in Table 9-3, after accounting for consistency with background, areas and noncarcinogenic COCs in soil based on the results of the RME analysis are as follows (Tables 9-4 and 9-5 are identical to 9-3 for noncarcinogenic COCs):

- <u>AOC 1</u> – PCBs and naphthalene,
- <u>Block A</u> – manganese, and
- <u>AOC 13</u> – naphthalene.

With regard to naphthalene, the models used by USEPA to estimate volatilization from soil to ambient air are known to be conservative (e.g., assume infinite source), as discussed in USEPA guidance (2002b). It is very likely that use of more refined volatilization modeling methods, such as EMSOFT, would result in acceptable ambient air concentrations of naphthalene and the resulting hazard indices for naphthalene in AOC 1 and AOC 13 would drop to below 1.

The only noncarcinogenic COC for sediment based on the results of the RME analysis is PCBs (based on potential bioaccumulation into fish tissue). PCBs is a sediment COC in both the reach of the Great Miami River adjacent to the Site and the reach adjacent to AOC 19 (where the former COG pipeline passed beneath the river). It should also be noted that upgradient concentrations of PCBs in sediment posed the highest fish consumption risk of the three reaches evaluated in the baseline HHRA.

The only noncarcinogenic COC for surface water based on the results of the RME analysis is mercury (potential bioaccumulation into fish tissue). Like PCBs, mercury is a surface water COC in both the reach of the Great Miami River adjacent to the Site and the reach adjacent to AOC 19.

As discussed in Section 7.0 (Uncertainty Analysis), there is considerable conservatism in the models used to estimate fish tissue concentrations of bioaccumulatable compounds like PCBs and mercury due to uptake from sediment and surface water. The overconservatism of the methods was discussed and supported by actual measured concentrations in Great Miami River surface water (for mercury) and fish tissue (for PCBs), as well as the upgradient sediment data set for PCBs. In summary, both PCBs in river sediment and mercury in river surface water appear to be related to background conditions in the Great Miami River and not the Site.

Based on the results of the RME analysis of the hypothetical future on-site worker's use of on-site groundwater as drinking water, there are a number of wells with COCs with hazard indices in excess of 1. As previously stated, a restriction against groundwater use on-site will be obtained. Therefore, while potential groundwater COCs are identified for completeness, remedial actions may not be warranted because an institutional control will prevent the exposure thereby eliminating any potentially unacceptable risks. Potential noncarcinogenic COCs were identified only in AOC 13 wells and include arsenic, cyanide, dibenzofuran, naphthalene compounds, and 2,4-dimethylphenol.

Based on the results of the RME analysis of the off-site resident at the Hamilton North Wellfield, four noncarcinogenic COCs were identified – cyanide, naphthalene, 2-methylnaphthalene, and 1-methylnaphthalene. Based on a review of the intermediate and deep groundwater data used in this scenario, potentially unacceptable risk to the off-site resident receptor is limited to wells located within AOC 13. The estimated risk is also overestimated, because it assumes that there is no attenuation or degradation of chemicals between the Site and the Hamilton North Wellfield. This is clearly an overly conservative assumption, especially for PAH compounds like the methylnaphthalenes, which tend to adsorb tightly to soil particles and do not move appreciably in groundwater.

Summary of CTE Results

Table 9-2 presents the results of the baseline HHRA for the CTE scenarios. Because of the limited number of noncarcinogenic COCs and areas identified in the RME risk characterization, the impact of the CTE analysis on eliminating additional COCs is limited. Based on the CTE analysis, manganese in Block A soil and mercury in Great Miami River surface water at AOC 19 (where the former COG pipeline crossed beneath the river) are eliminated as potential noncarcinogenic COCs. .

9.4.3 Summary of Risk Characterization Results

Based on the results of the baseline HHRA, the following compounds with a cumulative RME cancer risk above 10^{-6} and/or a cumulative noncancer HI of 1 (per toxic endpoint) were identified as potential COCs:

- arsenic, benzene, lead, manganese, potentially carcinogenic PAH, PCBs, and naphthalene in soil,
- potentially carcinogenic PAH in Riparian Area (AOC 22) hydric soil,
- potentially carcinogenic PAH and PCBs in Great Miami River sediment,
- mercury in Great Miami River surface water, and
- arsenic, benzene, potentially carcinogenic PAH, cyanide, and other inorganics and organics in groundwater from AOC 13 that is assumed to be used as drinking water at some point in the future.

All of the potential COCs identified based on the results of the RME risk characterization were carried forward into the development of remedial goal options (RGOs), which are presented in Section 8.0. As discussed with USEPA, RGOs for potentially carcinogenic COCs were derived for three target risk levels within the USEPA's target risk range (10^{-6}, 10^{-5}, and 10^{-4}). This approach provides a range of RGOs that fall within the USEPA target risk range.

It is important to note that several of the COCs identified above were found to be consistent with site-specific background. USEPA guidance does not require remediation to levels below background (USEPA, 2002f). Further, in correspondence to AK Steel dated August 26, 2008, USEPA confirmed the approach of taking background issues into consideration in the Uncertainty Analysis, and addressing site-specific background issues at the end of the risk characterization (USEPA, 2008b). When site-specific background is taken into consideration, a number of the COCs identified above are eliminated including arsenic and lead in soil in all areas, and potentially carcinogenic PAH in soil most areas. When site-specific background is factored into the

RME risk results, Site risks drop below 10^{-6} in several exposure areas including AOC 2, AOC 18 & 21, AOC 19, the Riparian Area (AOC 22), and AOC 7 (intermittent stream).

Background is also an important consideration for the two bioaccumulatable compounds identified as COCs in the Great Miami River (PCBs and mercury), as well as PAHs. When upgradient and regional concentrations of PCBs in Great Miami River sediment and mercury in Great Miami River surface water are considered, potential fish consumption risks for a recreational angler also drop below the target risk benchmarks. When upstream concentrations of PAHs in the Great Miami River sediment are taken into account, PAHs in sediment samples adjacent to the Site can in general be shown to be due to upstream conditions and not solely attributable to the Site.

In summary, it is critical that background conditions be carefully considered when interpreting the HHRA results for the Site.

While the risk results have been presented and discussed in the context of a 10^{-6} risk level as requested by USEPA, risks are also presented within the full USEPA target risk range of 10^{-6} to 10^{-4} to provide a more comprehensive and transparent interpretation of the results. Tables 9-3, 9-4, and 9-5 present summaries of potential COCs for each medium of interest, after accounting for consistency with background, at risk levels of 10^{-6}, 10^{-5}, and 10^{-4}, respectively.

As shown in Tables 9-4 and 9-5, which summarize potential COCs at 10^{-5} and 10^{-4} risk levels, respectively, potential RME COCs, after accounting for consistency with background, are limited to:

- One or more potentially carcinogenic PAH in soil at AOC 1, Southern Parcel and AOC 13,
- Benzene in AOC 1 and AOC 13 soil (at 10^{-5} risk level only),
- Manganese in Block A soil,
- Naphthalene in AOC 1 and AOC 13 soil,
- PCBs in AOC 1 soil, and
- Arsenic, cyanide, and multiple organics in groundwater in AOC 13 wells (for both on-site and off-site drinking water scenarios).

When the results of the CTE analysis are also considered, and assuming a cumulative Site risk of 10^{-4}, the vast majority of the Site is shown to pose acceptable risk, as shown in Table 9-5. The remaining COCs and areas that pose unacceptable risk after accounting for consistency with background are:

- Naphthalene in AOC 1 and AOC 13 soil, and
- Multiple COCs in AOC 13 groundwater (used as drinking water).

The identification of groundwater COCs based on the presumption of future use of on-site groundwater as drinking water is overly conservative given that groundwater is not currently used as an on-site drinking water source and institutional controls will be proposed to prohibit use of groundwater at the Site as a drinking water source. Thus, the drinking water pathway evaluated in this risk assessment is truly a hypothetical one.

In summary, a number of COCs, media, and areas of concern are identified when the lower end of the USEPA's acceptable risk range (10^{-6} to 10^{-4}) is used. However, the majority of the potential carcinogenic risks estimated in this baseline HHRA do not exceed the upper end of the USEPA's acceptable risk range of 10^{-6} to 10^{-4} for RME scenarios. As stated in USEPA guidance (USEPA, 1991a), remedial actions are typically not warranted "where the cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4}, and the non-carcinogenic hazard quotient is less than 1." Thus, for the majority of the Site, remedial action is not expected to be necessary based on the results of this site-specific baseline risk assessment and assuming that future residential use is prohibited via institutional controls. Based on the body of data presented in this risk assessment, including, but not limited to, the documented upstream sediment concentrations of several COCs, the ubiquitous nature of certain COCs such as PAHs in industrialized river systems, and the absence of greater detections of potentially bioaccumulative compounds adjacent to the Site versus upstream, no human health risk above background (or upstream conditions) is present to warrant additional evaluation or action in the Great Miami River. Therefore, it is concluded that no further investigation of or response action for the Great Miami River is warranted for this Site under CERCLA and the NCP. All relevant information is provided in this baseline risk assessment, including the results of background, CTE, and RGO evaluations, such that informed risk management decisions can be made for Site soil and groundwater.

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